PLANT DISEASES

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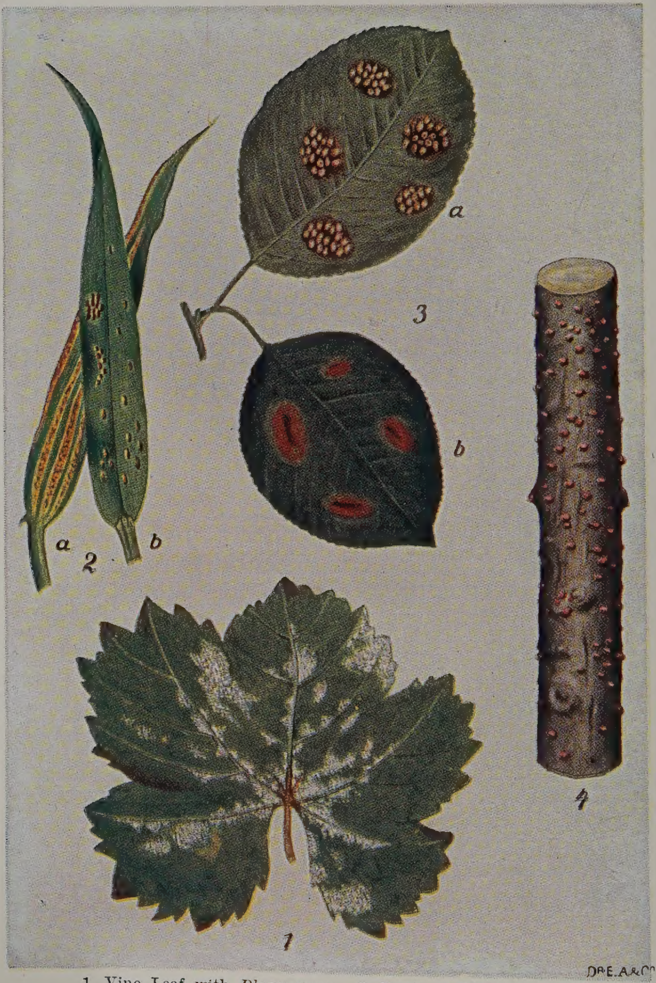
PLANT DISEASES



1, Vine Leaf with *Plasmopara*. 2, Rusts of Cereals—*a*, Yellow Rust (*Puccinia glumarum*); *b*, Brown Rust (*P. dispersa*). 3, Trellis Rust (*Roestelia cancellata*) on Pear Leaves—*a*, Aecidia; *b*, Spermogonia. 4, Coral Spot (*Nectria cinnabarina*).

PLANT DISEASES

BY

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TRANSLATOR'S PREFACE

Although many English books on plant diseases have been published, it is believed that this translation of Dr. Bruck's excellent little treatise will be useful as a concise introduction to the subject. It has also a special value of its own, as it lays stress on the changes produced by disease in cultivated plants, as against the usual practice of attaching most importance to the characters and life-histories of pests. One or two small additions by the translator are distinguished by the use of square brackets. The low price at which the English edition is issued will recommend it to those who desire a brief up-to-date outline of this important subject, and will enable it to be used as an auxiliary to larger and more ambitious works.

J. R. AINSWORTH-DAVIS.

CIRENCESTER,
October, 1912.

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PLANT DISEASES

CHAPTER I

INTRODUCTION—LINES AND METHODS OF WORK—AIMS

Plant Pathology.—The study of plant diseases is a young science, and the course of its development is intimately associated with that of general botany (anatomy and physiology) and cryptogamic botany. The study of most plant diseases is based on a knowledge of these branches of botany, and before they were sufficiently developed *scientific* investigation of such diseases was impossible. Even in the first half of the last century our knowledge of these branches was comparatively small, as will be seen from the following review of what was then known of plant diseases.

The practical man—farmer, gardener, or forester—had long been familiar with a number of plant diseases, and attributed them to the influence either of the weather or of animal pests. Such knowledge goes back to very remote times. The most ancient accounts of husbandry we possess include descriptions of plant diseases and the attempts made to deal with them. The Bible, and classical writers such as Aristotle, Theophrastus, and Pliny allude to various diseases of crops. The interest then displayed in these, as also during the Middle Ages down to the Renaissance, was in the main of a purely practical character, for the requisite knowledge on which to base a recognition of the *causes* of disease was still lacking, and even in the eighteenth century and the beginning of the nineteenth such knowledge was but slightly increased. From medieval times onwards, however, date various systematic collections and descriptions of plant diseases (contained in textbooks and handbooks), insufficient in character and mostly designed for practical purposes. Attempts were also made to compare the diseases of plants with those of human beings.

What we now call *infectious diseases* (due to microscopic organisms, such as fungi and bacteria) could not be explained at a time when the lower forms of life were believed to be spontaneously generated, and what we now know to be definite agents of disease were simply regarded as decayed spots or dead parts of a plant.

The rise of plant pathology in the first half of the nineteenth century claims our special attention. Here, as in every science, different lines of study successively came into prominence. There was a period when the part played by the living enemies of plants (pests) attracted less and less attention, owing to the increasing importance of chemistry. Even Justus von Liebig, the founder of agricultural chemistry, endeavoured to prove that unfavourable physical and chemical conditions in the soil were the sole causes of plant diseases. Owing to the great influence exerted by him and his school all earlier views as to the nature of such diseases were discredited.

Distortion, decay, and other abnormal appearances among plants were universally attributed to a disturbance in nutrition, and explained as due to excess, defect, or absence of some essential part of the food. Gradually, however, the rapid succession of results obtained by cryptogamic botanists showed the unprejudiced observer that such a one-sided interpretation of facts was out of the question. Repeated experiment proved that when certain small fungi were transferred to sound plants in a suitable way they produced the symptoms presented by diseased ones. More and more species of fungi were discovered, and their life-histories carefully investigated. To this period belong some important compilations on the literature of cryptogams, fungi more especially.

One circumstance in particular everywhere stimulated the new direction of work and directed attention to fungoid pests, i.e. the wholesale epidemics which inflicted crushing losses on that part of the population of West Europe engaged in the cultivation of plants. First came the Potato Disease, caused by the *Phytophthora* fungus, which jeopardized in several countries the culture of an important article of food for human beings and stock. Then followed great devastations in the wine-producing lands, where also a fungus (a true mildew) was discovered to be the cause of wholesale disease. Many attacks (Smut, Rust) known for thousands of years were now identified as being of fungoid nature. Among the first investigators of diseases of the kind may be mentioned Schacht, Julius Kühn, and de Bary, and their work may be assigned to about the middle of last century. While these scientists devoted themselves entirely to the injurious cryptogams of agricultural crops, Willkomm, and especially Robert Hartig, investigated those affecting forestry. During the following period of rather less than fifty years the active research work which was undertaken, especially by German scientists, included not only investigation of the organisms giving rise to the most important infectious diseases, but also a thorough study of the habits and life-histories of animal pests producing pathological changes in plants. The enormous damage caused by the plant-bug *Phylloxera* to the vine-growing parts of France and adjoining districts, and the injuries effected by certain insects on large forest areas, may be particularly mentioned as stimulating detailed investigation of the animal pests injurious to plants.

Such industries as agriculture and forestry have always had the greatest interest in the elucidation of plant diseases. After it was realized what enormous annual losses were due to these diseases, the organization of plant protection naturally followed. In 1890, under the guidance of Julius Kühn, A. B. Frank, and Paul Sorauer, the German Agricultural Society established a special branch for the purpose. Since then the society has conducted an unceasing campaign against plant diseases by issuing regular reports and statistics, and establishing experimental stations and bureaus. Nor has the German Government been idle. In 1897, acting with the advice of A. B. Frank, the Imperial Department of Hygiene established a special section for the purpose indicated. This has since developed so extensively that an independent "Biological Institute for Agriculture and Forestry" has arisen from it. To this institute, which has been fully equipped by the Government, are attached the most prominent German exponents of plant pathology (Aderhold, Appel, Behrens, Busse, Hiltner, Hollrung, O. Kirchner, J. Kühn, Rörig, Sorauer, von Tubeuf, and others), who are also responsible for its official publication (the *Beirat*).

The example of Germany has been followed by the other civilized countries of the world.

While during the last period in the history of our subject every year has witnessed the discovery of new pests and the investigation of their life-histories, fresh ground has been broken since the beginning of the present century. Apart from answering practical questions in the less interesting domain included under plant protection, the science was until then chiefly concerned with the actual agents of infectious diseases, and to a less extent with the nature and development of pathological changes. But our present knowledge enables us to definitely assert that diseases due to pests constitute only a small part of the subject of vegetable pathology. Atmospheric influences, such as warmth (heat), cold (frost), wind, drought, moisture, electric currents, light, gases, &c., as well as the chemical and physical composition of the soil, are of the greatest significance in the development of diseases. These influences are able directly to effect injuries on plants, and are also indirectly harmful by weakening the vital functions so as to bring about a predisposition to the attacks of pests. Just as the tubercle bacilli are unable to injure the sound normally acting lungs of a human being, so are a large number of the agents of infectious disease in plants powerless to damage a healthy plant with unimpaired vitality. This knowledge warns us that it is necessary to determine with accuracy whether a given pest may not be a secondary factor in the production of pathological lesions. The researches of Sorauer on the action of frost, which predisposes plants to fungoid and insect diseases, lends special support to such a view.

In fungoid attacks it is necessary to determine if the pest affects living or only dead tissue. In the former case we speak of **parasitism**, in the latter of **saprophytism**. But in many cryptogams there are transitions between these two conditions, on which account von Tubeuf draws a distinction between semiparasites and semisaprophytes. When, however, two organisms are intimately associated together to their mutual benefit as regards nutrition, this is described as a case of **symbiosis**. It is often difficult to accurately describe what takes place in a given instance; e.g. we know that there is a certain exchange of nutriment between the mistletoe and its host, but the former derives by far the greater benefit.

Individual pests are now regarded from different points of view. Some investigators, both among botanists and zoologists, chiefly concern themselves with systematic descriptions, and we are indebted to their researches for an easy means of recognizing organisms found upon diseased plants. The diagnosis of an actual disease, however, depends upon the aid given by plant physiology. It is then necessary to find out whether an organism associated with the diseased part of a plant is able to produce—under the same conditions—the same pathological appearances in healthy plants. This is the work of infection research.

If we have to transfer bacteria or fungi it is first necessary to prove that they are respectively alive or capable of germination. The methods of infection employed vary according to the nature of the research, whether carried out in the laboratory or a greenhouse on small objects, or in the field on a large scale.

In the former case we inoculate by means of a sterile needle, which is either simply brought into contact with the part to be experimented upon or made to puncture it. In the case of **fungi** either spores or mycelium may be used for inoculation. Fungi thrive best in a warm damp atmosphere, so the inoculated object (e.g. potato, turnip, pot plant) is placed in a damp chamber, either in a warm room or a thermostat. Air-tight glass and porcelain vessels, lined with wet blotting paper, are particularly suitable for damp chambers.

When fungoid attacks on larger quantities of material have to be investigated a gardener's syringe can be used, filled with water to which have been added the spores or mycelium from diseased plants. Infection can often be effected by bringing diseased plants into the neighbourhood of the healthy material used for research.

Sometimes only mycelium is to be found on an infected plant. We have then to identify this, finding out whether it belongs to a known species. For this purpose the mycelium is transferred to artificial or natural nutritive media. It may then pass into the spore-bearing or fruit-forming stage. Artificial solutions must, of course, be sterile, and they ought to contain the substances present in the diseased specimens. Fruit juice and meat broth (*bouillon*) are frequently employed both for fungi and bacteria. Such media, and also those made up from chemical reagents, may be used either in the liquid or solid form. In the latter case gelatine or agar is added. Fungi generally prefer acid media and bacteria alkaline ones.

The chemical changes which a parasite brings about during its destructive work can also be demonstrated by the culture methods mentioned. Certain fungi, for example, can be proved to be alkali formers. From this it can be deduced that bacteria, which as just mentioned are particularly active in nutritive media of alkaline reaction, may be expected in nature to settle very quickly on substrata diseased by the attacks of such fungi. Several diseases of root crops serve to illustrate this point.

The methods of research described indicate whether a pest has a directly injurious effect on the object it attacks, or first secretes a ferment (enzyme) which kills part of the infected plant and thus enables the fungus to live saprophytically upon the dead tissue. A very instructive example of the kind is given by de Bary with reference to the infection of various plants by *Sclerotinia Libertiana* (p. 67).

By variations in the composition of the media employed, as also by the action of alterations in temperature and amount of moisture, special forms of propagation or reproduction may often be brought about in microorganisms under culture. The botanist George Klebs has been especially instrumental in elaborating this kind of research. He has been able in this way, both in lower and higher plants, to produce at will modifications of development. This method also enables us to determine the vital functions of a pest, and by its means we can artificially set up pathological changes in the plant body. (Here are included alterations in the growth of tissue and in development, i.e. deviations from the normal structure and functions of a plant, usually associated with alterations in shape.)

This experimental direction of research has been one of the chief lines of plant pathology since the beginning of the present century, and by its means—in particular—the possibility of investigating the causes of disease has been for the first time proved. One of the branches of work in experimental pathology is the investigation of the conditions which predispose to diseases of the most various kind. To these belong the atmospheric factors already mentioned (p. 13), which are also able of themselves to bring about pathological disturbances.

Experimental work in this field is being carried on at the present time. Among investigations of the kind may be mentioned: the researches of Sorauer upon injuries by frost, those of Müller-Thurgau, Molisch, and Metz on the freezing of plants, those of von Tubeuf on the action of electric currents and other agents on plants. The injuries effected by gases (e.g. sulphurous acid) have also been studied (Haselhoff-Lindau, Wieler).

Beside working in the direction of experimental physiology, pathology is also concerned with investigating the anatomy and histology of diseased tissues. Ernst Küster's *Pathological Plant Anatomy* (1903) gives a general account of this subject based on our present knowledge. The task of modern pathology is to work along the two lines mentioned, which represent a branch of pure botany as compared with the applied subject of plant protection.

One subdivision of plant pathology—**plant hygiene**—endeavours to remove as far as possible all the conditions which favour disease. Among other things coming under this head are the breeding of resistant varieties, rotation of crops as well known to the agriculturist, the proper storage of fruit and grain in suitable places during the winter, and various other matters.

Another section of plant protection is that dealing with the treatment of disease. As in human pathology, the means employed for destroying parasitic pests are partly operative and partly chemical.

Predisposition to disease has already been mentioned, and in briefly returning to this subject we shall adopt the division given by Robert Hartig in his textbook, where he distinguishes between five categories of disease "foundations".

Under tendencies due to **habitat** are included all conditions unfavourable to plants caused by their position and its characteristics. An example is found in the contours of the surface, as in "frost pits". Another case is the **exposed position** of some trees, giving but little shelter from lightning and hail. We should also remember here that the lodgment and development of parasitic fungi are favoured by damp warm air.

Hartig applies the term **time-tendency** to those stages in plant development which are particularly sensitive to certain infiuences (e.g. frost or fungoid attack) either as a result of anatomical structure or physiological condition. The early stages of plants and the resting stage in the growth of plant tissue may be mentioned here.

An **individual, inherited tendency to disease** is seen, for example, in plants possessing an epidermis insufficiently resistant to smoke or other chemical agents. Many plants are protected from definite tendencies to disease by the late development of their buds, which enables them to escape spring frosts and many parasitic infestations.

Acquired tendencies to disease include such things as the appearances presented by plants reared in the damp air of forcing houses when they are brought into dry air. They are then particularly liable to suffer from desiccation.

The last division, **predisposition to disease**, includes all kinds of injuries due to animals or the weather which facilitate the entry of pests and the agents of decay.

The limits of space forbid the mention of more than a very few cases under the above headings, but it would be possible to give any number of examples, all of them related to the characteristics of the plants affected.

This little book describes the most important diseases—chiefly those attacking our cultivated plants—and emphasis is laid on pathological modifications of the plant body. The life-histories of pests are only treated with the detail necessary for recognition of the course of disease. To the main chapters (III to VIII) is prefixed a shorter one (II), referring pests to their systematic position, and giving the most essential points in their life-histories. Animal forms are only briefly treated. The last chapter (IX) deals with the methods of greatest utility in plant protection.

CHAPTER II

SUMMARY OF CLASSIFICATION AND STRUCTURE OF PESTS

A. PLANT PESTS

I. **Myxomycetes** or **Mycetozoa** (Slime Fungi). [Regarded as animals by many authorities.]

The lowest group of plants, devoid of chlorophyll. The body is a naked mass of protoplasm (plasmodium), living in the cells of the host in parasitic species. Creeping amœboid movements. Reproduction: the plasmodium breaks up into spores, from which emerge naked masses of protoplasm that fuse into new plasmodia.

Plasmodiophora brassicæ, Wor. (Finger-and-toe, p. 78).

II. **Schizomycetes** (Bacteria)

Simple unicellular or thread-shaped plants, only visible under high powers of the microscope. Shape: spheres, rods, screws, straight filaments. Reproduction: asexual, by fission. In some cases formation of spores (resistant cells with firm investments). Movements by cilia.—*Bacillus phytophthorus*, Appel (Black-shank of potato, p. 58); *Clostridium butyricum* [*Amylobacter Clostridium*] (Bacterial decay of potato, p. 58); *Bacillus betæ* (Beet rot, p. 67); various bacteria (Scab and Rot, diseases of Crucifers and vegetables, p. 79).

III. **Fungi**

Plants devoid of chlorophyll, which feed on organic compounds. Parasites which prey on living organisms; and saprophytes living on dead organisms, or the products of their decay (organic substances such as humus; sugar solutions). The fungoid cells are united into threads—**hyphæ**—aggregated into the vegetative plant body or **mycelium**. This may live on the surface of the host plant, or penetrate into its cells, sometimes by means of special suctorial organs or **haustoria**. The reproductive organs develop in the mycelium, and may be—

1. **Conidiophores**, simple or branched, which are

usually found on the surface of the host. These produce **spores** or **conidia** by abstriction—

(*a*) Developed separately.

(*b*) Developed in numbers in **sporangia**, and liberated by rupture of their walls.

Under favourable conditions the conidia germinate in suitable substrata, by protrusion of germinal hyphæ which grow into mycelia.

2. Sporangia producing motile **swarm spores**, which live in water (fig. 1).

3. **Sexual spores**, produced from egg cells fertilized by spermatozoids.

4. **Ascospores**, developed in tubular sporangia—**asci** (figs. 4 and 7). The asci are often associated with sterile hyphæ—**paraphyses**—in special fruit bodies. These are either closed **perithecia** or open **apothecia.** The former may either be sunk below the epidermis or project outside it. Apothecia, and some perithecia, do not develop directly from the mycelium, but from a hard structure or **sclerotium**, made up of hyphæ compacted together, and representing a resting stage. Stalked

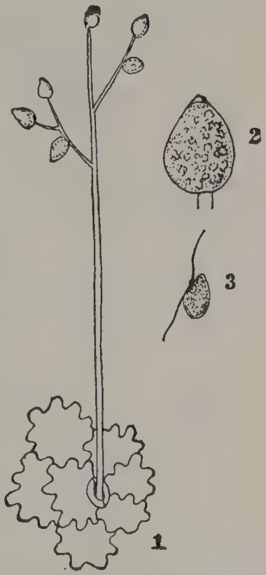

Fig. 1.—Potato Disease (*Phytophthora infestans*, de By.)

1, Sporangiophore protruding from a stoma of a potato leaf. 2, Sporangium. 3, Swarm Cell. (Enlarged.)

spore fruits grow out from these sclerotia (figs. 7 and 13*a*). In some ascus-bearing fungi (Ascomycetes) the formation of asci is the result of sexual reproduction.

5. The Ascomycetes—in addition to the spore fruits mentioned—also bear **pycnidia** or **spermogonia**, in which conidia are formed, either abstricted from conidiophores or developed in sporangia. In some groups only one kind of spore fruit is known, and the development is therefore considered incomplete (*Fungi imperfecti*).

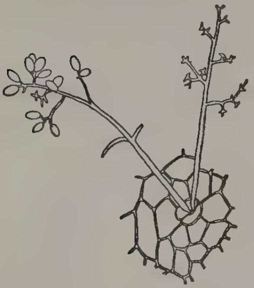

Fig. 2.—Downy Vine Mildew (*Plasmopara* [*Peronospora*] *viticola*, de By.)

Conidiophores growing out of a stoma of a vine leaf. See also frontispiece. After F. Cohn (enlarged).

6. **Basidia.**—Cells from which conidia are abstricted in small numbers. They are borne on large specialized structures formed from compacted hyphæ (Toadstools: Basidiomycetes).

CLASSIFICATION OF FUNGI

1. Phycomycetes (lower and alga-like fungi).
2. Ascomycetes (ascus-bearing fungi).
3. Ustilagineæ (Smuts and Bunt).
4. Uredineæ (Rusts).
5. Basidiomycetes (Toadstools, &c.).
6. Fungi imperfecti.

1. Phycomycetes

(*a*) **Oomycetes.**—Tubular, branched, unicellular mycelium. Oospores produced by sexual reproduction.

Fam. *Peronosporaceæ.—Pythium de Baryanum*, Hesse (Damping-off Disease of beet and mangold seedlings, p. 65). *Phytophthora infestans*, de By. (Potato Disease, fig. 1, p. 21; *P. omnivora*, de By. [=*P. fagi*, R. Htg.] (Seedling Disease of beech, p. 118); *Peronospora Schachtii*, Fkl. (False Mildew of beet, p. 68); *P. viciæ*, Berk. (False Mildew of vetches, p. 72); *P. trifoliorum*, de By. (False Mildew of clover and lucerne, p. 73); *P. parasitica*, de By. (False Mildew of rape, cabbage, and turnip, p. 80); *P. Schleideniana*, Ung. (False Mildew of onion, p. 82); *P. spinaciæ*, Laub. (False Mildew

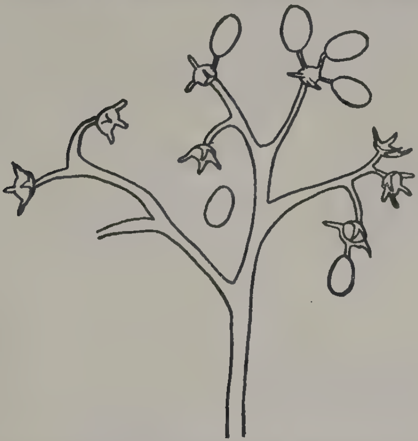

Fig. 3.—White Rust of Lettuce (*Bremia lactucæ*, Reg.). Forked conidiophores (enlarged)

of spinach, p. 81); *Plasmopara* [*Peronospora*] *viticola*, de By. (Downy Vine Mildew, p. 100, fig. 2, Frontispiece, 1); *Cystopus* [*Albugo*] *candidus*, Lév. (White Rust of rape, cabbage, and turnip, p. 79); *Bremia lactucæ*, Reg. (White Rust of lettuce, p. 80).

Fam. *Saprolegniaceæ.—Aphanomyces* (Damping-off Disease of beet and mangold seedlings, p. 65).

(*b*) **Chytridiaceæ.**—Simply organized parasites, producing swarm cells which become ordinary cells.

Olpidium brassicæ, Wor. (Cabbage-seedling Disease, p. 79); *Chrysophlyctis endobiotica*, Schilb. (Wart Disease of potato, p. 61).

2. Ascomycetes

Multicellular mycelium, in which are developed spore fruits containing asci. These rupture to liberate the ascospores. There are two groups—(*a*) Gymnoasci (asci exposed, fig. 4); (*b*) Carpoasci (asci within spore fruits, fig. 5, 2).

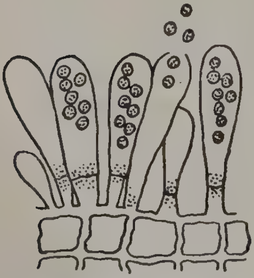

Fig. 4.—Plum Pockets (*Exoascus pruni*, Fkl.). Asci with ascospores (enlarged)

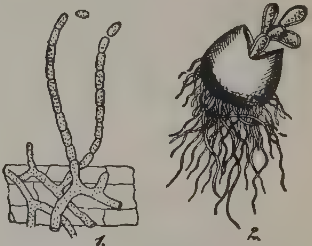

Fig. 5.—Corn Mildew (*Erysiphe graminis*, Lév.)

1, Conidiophores, with rows of conidia separated by abstriction. 2, Ruptured perithecium with projecting asci. (Enlarged.)

(*a*) **Gymnoasci.**—*Exoascus* [*Taphrina*] *pruni*, Fkl. (Pocket Disease of damsons and plums, p. 91, fig. 4); *E. cerasi*, Fkl. (Witches' Brooms of cherry, p. 92); *E. deformans*, Berk. (Leaf Curl of peach, p. 93).

(*b*) **Carpoasci.**—

a. Perisporiaceæ.—Closed capsule-like perithecia, which break open by the action of the weather and other agents to liberate the asci.—*Erysiphe graminis*, Lév. (Corn Mildew, p. 43, fig. 5); *E. Martii*, Lév. (True Mildew of Leguminosæ, p. 73); *E.* [*Uncinula*] *necator*, (Schw.) Burr, and *Oidium Tuckeri*, Berk. (Vine Mildew, p. 99, fig. 6); *Sphærotheca Castagnei*, Lév. (Hop Mildew, p. 82); *S. pannosa*, (Wallr.) Lév. (Rose Mildew, p. 109; *S. mors-uvæ*, (Schw.) Berk. et Curt., and *Microsphæra grossulariæ*, (Wallr.) Lév. (Gooseberry Mildew, p. 90).

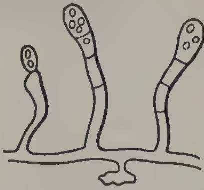

Fig. 6.—Vine Mildew (*Oidium Tuckeri*, Berk.) showing conidia and a sucker (haustorium)—enlarged

β. Pyrenomycetes.—The perithecia have small openings through which the ascospores escape. They are minute flask-shaped or globular receptacles, borne either directly on the mycelium, or else a number of them are sunk within a special structure (stroma). Sclerotia are formed. Conidia are developed as well as ascospores. They are mostly parasites on leaves and bark.

Claviceps purpurea, Tul. [= *Sphacelia segetum*, Lév., and *Secale cornutum*] (Ergot, p. 44, fig. 13); *Ophiobolus herpotrichus*, Sacc. (Wheat-haulm Killer, p. 47); *Leptosphæria herpotrichoides*, de Not. (Rye-haulm Breaker, p. 47); *Cladosporium herbarum*, Link, and *Pleospora* (False Smut of corn, p. 47); *Sphærella exitialis*, Mor. (Corn-leaf Fungus, p. 49); *S. bellona*, Sacc. (White Spot of rosaceous fruits, p. 89); *S. fragariæ*, Sacc. (Leaf Spot of strawberry, p. 93); *S. laricina*, Hess (Larch Scab, p. 128); *Septoria graminum*, Desm. (Corn-leaf Fungus, p. 49); *S. pyricola*, Desm., and *S. nigerrima*, Fkl. (Leaf Spot of pear, p. 88); *Rhizoctonia solani*, Kühn [= *Hypnochus solani*, Prill. et Del.] (Potato Scurf, p. 59); *R. violacea*, Tul. (Violet Root Fungus of beet, mangold, and lucerne, pp. 68 and 73); *Fusarium oxysporum* and *F. solani*, Sacc. (Dry Rot of potato, p. 60); *F. beticola*, Frank (Dry Rot of beet, p. 64); *Fusicladium dendriticum*, Fkl. [= *Venturia inæqualis*, Aderh.] (Apple Scab, p. 87); *F. pyrinum*, Fkl. [= *V. pyrina*, Aderh.] (Pear Scab, p. 88); *Stigmatea mespili*, Sor. (Leaf Brown of rosaceous fruits, p. 89); *Gnomonia erythrostoma*, Auersw. (Cherry Leaf Scorch, p. 90); *Polystigma rubrum*, Tul. (Plum Leaf Blister, p. 91); *Læstadia* [*Physalospora*] *Bidwellii*, Kühn (Vine Black Rot, p. 103); *Acladium interaneum*, Thürn. (Leather Berries in Tyrolese vines, p. 103); *Dematophora necatrix*, R. Htg. (White Root Rot of vine, p. 103); *Nectria cinnabarina*, Tode (Coral Spot, p. 111, Frontispiece, 4); *N. ditissima* (Apple Canker, p. 118); *Aglaospora taleola*, Tul. (Oak Canker, p. 117); *Rosellinia quercinia*, R. Htg. (Oak-seedling Disease, p. 117).

γ. *Discomycetes.*—Stalked disks or cups (apothecia) grow from the sclerotium, and in these asci are developed among sterile hyphæ (paraphyses) (fig. 7). Conidia are produced on conidiophores.

Sclerotinia Libertiana, Fkl. (Sclerotium Disease of beet, mangold, and rape, pp. 67 and 81, fig. 7); *S. cepæ*, Lib. (Sclerotium Disease of onion, p. 82); *Botrytis cinerea*, Pers. (Wine Mould, &c., p. 104); *Sclerotinia trifoliorum*, Eriks. (Clover Sclerotinia, p. 75); *Monilia fructigena* [and *cinerea*, Pers.] (Cushion Mould of rosaceous fruits, p. 94); *Peziza Willkommii*, R. Htg. (Larch Canker, p. 126); *Pseudopeziza trifolii*, Fkl. (Clover Leaf Spot, p. 75); *P. tracheiphila* (Red Leaf Spot of Vine, p. 102); *Rhytisma acerinum* (Sycamore Leaf Blotch, p. 112); *Hysterium* [*Lophodermium*] *pinastri*, Schrad. (Pine Scab, p. 128); *H.* [*L.*] *nervisequium* DC. (Spruce Scab, p. 128).

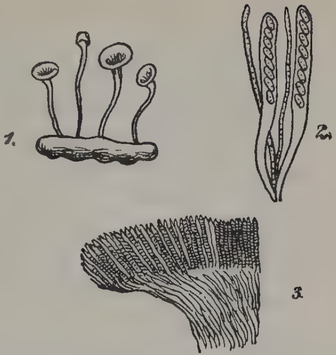

Fig. 7.—Sclerotium Disease of Beet and Rape (*Sclerotinia Libertiana*)

1, Sclerotium with apothecia. 2, Asci with ascospores and paraphyses (much enlarged). 3, Longitudinal section through part of an apothecium. (Enlarged.)

3. Ustilagineæ

[For details of life-history and parasitism, see p. 34]

Tilletia caries, Tul. and *T. lævis*, Kühn (Wheat Bunt, p. 35); *Ustilago tritici*, (Pers.) Jens. (Wheat Smut, p. 36); *U. avenæ*, Pers. (Naked Oat Smut, p. 36); *U. Kolleri*, Wille (Covered Oat Smut, p. 37); *U. nuda hordei*, Jens. (Naked Barley Smut, p. 37); *U. tecta hordei*, Jens. (Covered Barley Smut, p. 37); *Urocystis occulta*, Rabh. (Rye Smut, p. 37); *U. maydis*, Lév. (Maize Smut, p. 37); *U. destruens*, Schlechtd. (Millet Smut, p. 38).

4. UREDINEÆ

[For details of life-history and parasitism, see p. 38]

(*a*) **Puccineæ.**—*Puccinia graminis*, Pers. (Black Rust of corn; æcidia on barberry, pp. 41 and 110); *P. glumarum*, Eriks. et Henn. (Yellow Rust; æcidia unknown, p. 43, Frontispiece, 2); *P. dispersa*, Eriks. (Brown Rust; æcidia on Anchusa, p. 43); *P. coronifera avenæ*, Kleb. (Crown Rust; æcidia on Rhamnus, pp. 43 and 111); *P. asparagi*, DC. (Asparagus Rust, p. 82); *Pucciniastrum padi* [= *Æcidium strobilinum*, Alb. et Schw.] (Spruce-cone Fungus, p. 129).

(*b*) **Phragmideæ.**—*Phragmidium subcorticium*, Schrk. (Rose Rust, p. 109).

(*c*) **Melampsoreæ.**—*Melampsora lini*, Wtr. (Flax Rust, p. 83); *M.* [*Calyptospora*] *Goeppertiana*, Kühn, with the æcidial form *Æcidium columnare*, Alb. et Schw. (Silver Fir Rust, p. 127); *M. tremulæ*, Tul. with the cæoma form, *Cæoma pinitorquum*, A. Br. (Pine Branch Twist, p. 124); *Melampsorella cerastii* [= *Æcidium elatinum*, Alb. et Schw.] (Canker and Witches' Brooms of Silver Fir, p. 125).

(*d*) **Chrysomyxeæ.**—*Chrysomyxa abietis*, Wallr. (Spruce Rust or Blight, p. 127); *C. rhododendri*, DC., with the æcidial form, *Æcidium abietinum*, Alb. et Schw. (Spruce Blister Rust, p. 127).

(*e*) **Uromyceæ.**—*Uromyces betæ*, Tul. (Beet Rust, p. 68); *U. pisi*, de By. (Pea Rust, p. 72); *U. trifolii* (Clover Rust, p. 72); *U. orobi*, Wint. (Vetch Rust, p. 72); *U. phaseolorum*, Tul. (Bean Rust, p. 72); *U. anthyllidis*, Schröt. (Lupine Rust, p. 72).

(*f*) **Gymnosporangeæ.** — *Gymnosporangium sabinæ*, Dicks., with the æcidial form *Rœstelia cancellata*, Reb.

(Cluster Cups or Trellis Rust of pear, p. 89, Frontispiece, 3).

(*g*) **Cronartieæ.**—*Cronartium ribicolum*, Dietr. (Blister Rust of gooseberry and currant), with *Peridermium strobi*, Kleb. (Blister Rust of Weymouth pine, p. 124); *C. asclepiadeum*, Willd., with *P. pini*, Willd. (Pine Blister Rust, p. 123).

5. Basidiomycetes

(*a*) **Polyporeæ.**—Parasites on wood and bark. Spore-producing body stalked or unstalked; woody or corky in texture. Sometimes projecting like a bracket from the bark of the host. *Polyporus* (Tree Fungus, see p. 119); *Merulius lacrymans*, Jacq. (Dry Rot of timber, p. 119); *Trametes radiciperda*, R. Htg. (Root Fungus of conifers, p. 121); *T. pini*, Fr. (Pine Fungus, p. 122).

(*b*) **Agaracineæ.**—Spore-producing body a soft "toadstool". *Agaricus melleus*, L. (Honey Fungus, p. 119).

6. Fungi imperfecti

Glœosporium caulincola, Kirch. (Clover Stem Scorch, p. 73); *G. Lindemuthianum*, Sacc. et Mgn. (Bean-pod Blotch Disease, p. 74); *Sphaceloma ampelinum*, de By. [= *Glœosporium ampelophagum*, Sacc.] (Grape Rot, p. 102); *Phoma betæ*, Frk. (Root Blight of beet and mangold, p. 64); *Coniothyrium* [*Phoma*] *diplodiella*, Sacc. (Vine White Rot, p. 103); *Cercospora beticola*, Sacc. (Beet Leaf Blotch, p. 68); *Ascochyta graminicola*, Sacc. (Corn Leaf Spot, p. 49); *A. pisi*, Lib. (Leaf and Pod Spot of pea, p. 75); *Helminthosporium gramineum*, Rabh. (Barley Leaf Brown, p. 48); *Sporidesmium exitiosum*, Kühn (causing a disease of rape, p. 81); *Stysanus stemonites*, [Pers.] Corda (Bristle Mould of stored potatoes, p. 60); *Cryptosporium leptostromiforme*, Kühn (Black Stem Spot of lupine, p. 74); *Clasterosporium carpophilum*, [Lév.] Aderh. (Gumming of peach, cherry, &c., p. 86); *Marsonia* and *Phyllosticta* (Hazel Leaf Spot, p. 93); *Cenangium abietis*, Duby (Cenangium Disease of pine, p. 126); *Oospora scabies*, Thaxter (Potato Scab, p. 61); *O.* sp. (Girdle Scab of beet, p. 65); *Alternaria solani*, Sor. (Early Potato Blight, p. 57).

IV. **Phanerogamous Parasites.** DICOTYLEDONS

Fam. *Loranthaceæ.*—Semiparasites, living on trees and shrubs. They abstract only water and inorganic compounds from their hosts, and, since they possess chlorophyll, do their own carbon assimilation, some of the elaborated substances passing into the host. *Viscum album* (Mistletoe, p. 115); *Loranthus europæus*, R. Htg. (p. 116).

Fam. *Convolvulaceæ.*—Cuscuteæ, parasites devoid of chlorophyll. The stem twines round that of the host, attaching itself by means of suckers (haustoria). *Cuscuta trifolii*, Bab. (Clover Dodder, p. 76); *C. europæa*, L. (Willow Dodder, p. 111).

Fam. *Orobancheæ.*—Root parasites devoid of chlorophyll. *Orobanche minor*, Stk. (Lesser Broom Rape of clover, p. 76).

B. ANIMAL PESTS

I. **Nematoda** (Eelworms)

(For details of life-history and parasitism, see p. 49.)

Tylenchus devastatrix [*dipsaci*], Kühn (Stem Eelworm of corn, Eelworm Disease of potato, pp. 50 and 62, fig. 14); *T. scandens*, Schneid. (Peppercorns or Purples of wheat, p. 50); *Heterodera Schachtii*, A. Schm. (Beet Sickness, p. 69); *H. radicicola*, Greef (Root-knot Disease, p. 71).

II. **Arthropoda**

1. ACARINA (Mites).—*Tetranychus telarius*, L. (Red Spider, p. 112); *Rhizoglyphus echinopus* (Bulb Mite, p. 62); *Eriophyes vitis*, Land. (Vine Mite, p. 108); *E. pyri*, Nalepa (Pear-leaf Blister Mite, p. 96); for other species of Eriophyes [Phytoptus], see p. 113.

2. INSECTA. — (*a*) **Thysanoptera.** — *Thrips cerealium*, Hal. (Corn Thrips, p. 51).

(*b*) **Diptera** (Flies, Gnats, &c.).—*Cecidomyia destructor*, Say, and *C. secalina*, Lw. (Hessian Fly, p. 52); *C. brassicæ*, Wtz. (Rape Gall-midge, p. 81); *C.* [*Hormomyia*] *fagi*, R. Htg. (Beech Gall-midge, p. 118); *Diplosis* [*Cecidomyia*] *tritici*, K. (Wheat Gall-midge, p. 53); *D. pyrivora*, Riley [= *Cecidomyia nigra*, Mg., and *C. pyricola*, Nörd.] (Pear Midge, p. 96); *Oscinis frit*, L., and *O. pulsilla*, Mg. (Frit Flies, p. 51); *Chlorops tæniopus*, Mg. (Ribbon-footed Cornfly, p. 53); *Anthomyia conformis*, Fall. (Beet and Mangold Fly, p. 71); *A. funesta*, Kühn (Lupine Fly, p. 77); *A. radicum*, L. (Cabbage-root Fly, p. 81); *A. antiqua*, Mg. (Onion Fly, p. 82); *Trypeta fulminans*, Mg. (Asparagus Fly, p. 82); *Spilographa cerasi*, F. (Cherry Fly, p. 96); *Sciara pyri*, Schm. (Black Pear Midge, p. 96).

(*c*) **Orthoptera.**—*Gryllotalpa vulgaris*, Ltr. (Mole Cricket, p. 55).

(*d*) **Hymenoptera.**—*Cephus pygmæus*, L. (Corn Sawfly, p. 54); *Rhodites rosæ*, L. (Rose Gall Fly, p. 110); *Athalia spinarum*, Fbr. (Turnip Sawfly, p. 71).

(*e*) **Hemiptera.**—*Jassus sexnotatus*, Fall. (Dwarf Cicada, p. 54); Aphides (Plant Lice, pp. 71, 77, and 94), *Siphonophora ulmariæ*, Schk. (Pea-leaf Aphis, p. 77); *Schizoneura lanigera*, Hsm. (Woolly Aphis, p. 94); *Phylloxera vastatrix* (Vine Louse, p. 105); *Aspidiotus perniciosus* (San José Scale, p. 84); *Chermes* spp. (Larch-gall Bugs, p. 130).

(*f*) **Coleoptera** (Beetles). — *Melolontha vulgaris*, L. (Cockchafer, p. 54); *Agriotes lineatus*, L., *A. sputator*, L., *A. obscurus*, L., and *Athous* spp. (Wireworms, pp. 54 and 62); *Plinthus porcatus*, Paur. (Hop Beetle, p. 83); *Haltica oleracea*, L. (Turnip Flea-beetle or Turnip Fly, p. 81); *Psylliodes chrysocephalus* (Rape Flea-beetle, p. 81); *Rhynchites betuleti*, Fbr. (Vine Leaf-roller, p. 108); *Bromius vitis*, Fbr. (Vine Leaf-borer, p. 108); *Anomala aënea*, Deg. (Vine Ground Beetle, p. 108); *Otiorhynchus sulcatus* (Vine Weevil, p. 108); *Anthonomus pomorum*, L., and *A. pyri*, Koll. (Apple and Pear Weevils, p. 96); *Zabrus gibbus*, Fbr. (Corn Ground Beetle, p. 54); *Cassida nebulosa*, L. (Tortoise Beetle, p. 71); *Silpha atrata*, L. (Beet Carrion Beetle, p. 71; *Scolytidæ* (Bark Beetles, p. 130); *Bruchus* spp. (Seed Weevils, p. 77).

(*g*) **Lepidoptera** (Butterflies and Moths).—*Pieris* spp. (Whites, p. 81); *Aporia cratægi*, L. (Black-veined White, p. 97); *Liparis dispar*, Sch. (Gipsy Moth, p. 97); *L. monacha*, L. (Nun Moth, p. 129); *Euproctis chrysorrhœa*, L. (Browntail Moth, p. 97); *Bombyx* [*Clisiocampa*] *neustria*, L. (Lackey Moth, p. 97); *B.* [*Gastropacha*] *pini*, L. (Pine

Moth, p. 129); *Agrotis segetum*, W. V. (Surface Caterpillars, pp. 54 and 62); *Plusia gamma*, L. (Silver-Y Moth, p. 77); *Mamestra pisi*, L. (Pea Moth, p. 77); *M. brassicæ*, L., and *M. oleracea*, L. (Cabbage Moths, p. 81); *Cheimatobia brumata*, L. (Winter Moth, p. 97); *Hibernia defoliaria* Cl. (Mottled Umber Moth, p. 97); *Geometra piniaria*, L., and *G. liturata*, Cl. (Pine Loopers, p. 130); *Noctua griseo-variegata*, Goetze (p. 130); *Cnethocampa pinivora*, Tr. (Pine Procession Moth, p. 129); *C. processionea*, L. (Oak Procession Moth, p. 117); *Carpocapsa pomonella*, L. (Codlin Moth, p. 96); *Grapholitha dorsana*, F., and *G. nebritana*, Tr. (Pea Moths, p. 77; other spp. injurious to forestry, p. 130); *G. botrana*, Schffn. (Vine Cross Moth, p. 107); *Conchylis ambiguella*, Hbn. (p. 107); *Tortrix pilleriana* Schffn. (p. 107).

CHAPTER III

PLANT DISEASES—AGRICULTURAL PESTS OF CEREALS

Our knowledge of DISEASES OF CEREALS goes back to very early times, for the farmers of antiquity were certainly familiar with Smut and Rust. Yet the study of these two diseases is one of the most modern tasks of plant pathology and plant protection, because they have an extremely serious influence on agriculture. In the single year 1891 the ravages of Rust represented a loss of over £20,000,000 to Prussian agriculture alone. The measures employed to cope with parasitic plant diseases, however, remained more or less empirical so long as the relations between the life-histories of pests and the course of disease in their hosts were imperfectly known.

We will first consider the diseases included under the names **Bunt** and **Smut**. These embrace pathological appearances of the most various kind, produced in grasses, especially cereals, by fungi belonging to the great group of Ustilagineæ. Their hosts are chiefly flowering plants. Every species is adapted to a particular host, and possesses a characteristic mode of life. The method of infection varies. Sometimes the germinal hyphæ of the conidia penetrate flowers, where development may take place either in the pistil and anthers only, or in the fruit and seed—more rarely they enter root, stem, or leaf.

The **spores** which spread the infection are very tenacious of life, and may remain dormant for several winters, retaining the power of germination even under conditions of extreme desiccation. When the environment is favourable, especially if the air and soil are damp, they give rise to vigorous germinal hyphæ, making up a **promycelium** (fig. 8). A germinal hypha may bring about direct infection, or it may produce conidia (asexual spores) by apical or lateral abstriction. These increase the chance of distribution. A hypha enters the host by piercing epidermal cells, after which it grows into a **mycelium** in the internal tissues. Young seedlings are particularly liable to attacks by this parasite. The mycelium grows in the stem, especially in the intercellular spaces. Destruction of tissue rapidly follows the production of spores, which are developed by segmentation and abstriction of hyphæ in some special part of the host, the nature of which depends upon the species to which the parasite belongs. In a short time this part will have been replaced by a brown or blackish mass of spores. This wholesale production of spores, which are blown away by the slightest breath of air, explains the rapid distribution of the pest. Seed corn with adherent spores, and dung containing infected straw, enable the infestation to persist from year to year. It has more recently been shown that seed corn may actually contain mycelium which has lived on from the previous year, when it developed in the ovaries (Brefeld, Hecke). At the beginning of the next vegetative period the mycelium resumes growth and produces spores. This has been confirmed by experimental infection of flowers.

Our present knowledge points to the use of **clean seed corn** only, or, if this is impossible, the grain should be **pickled**, steeped in hot water, or treated in some other way that will kill the adherent spores (p. 139). Only manure should be employed which is free from infected straw.

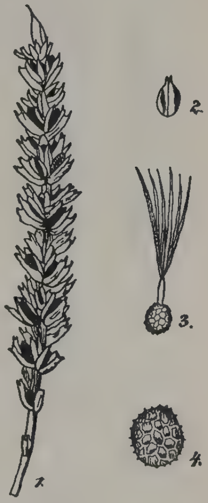

Fig. 8.—1, Bunted Ear of Wheat. 2, Diseased Grain. 3, Germinating Spore (enlarged). 4, Spore (much enlarged)

Certain species will now be considered in detail.

Bunt attacks wheat more particularly, but may also infect spelt and summer spelt. When the crop is ripe, bunted ears can easily be distinguished from sound ones (fig. 8). The former are often longer, and their glumes are generally more divergent. The bunted grains can be seen through these. Although such a grain retains its coat, the endosperm and embryo are replaced by a black mass of spores, which, when fresh, emit a strong smell resembling herring brine.

Bunted ears can be seen in almost every field of wheat. When present to an injurious extent the disease may destroy as much as half the crop. It is caused by two fungi — *Tilletia caries*, Tul., and *T. lævis*, Kühn. Only young seedlings are attacked, the germinal hyphæ of the spores piercing their epidermis. Mycelium thus develops in the stems, and spores are ultimately produced in the fruits.

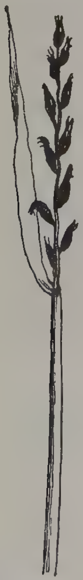

Fig. 9.—Smutted Ear

Smut attacks oats, barley, and wheat, black masses of spores replacing the normal contents of the flowers in the panicles or ears (fig. 9). They may ultimately be only covered by the epidermis of the bracts surrounding individual flowers, and this stage may persist for a tolerably long time in barley. When this membranous investment breaks away, the powdery spores are quickly removed by wind or rain, leaving nothing but the bare axis. In **Wheat Smut**, which is usually rare, the leaves may also develop diseased streaks. It is due to *Ustilago tritici*, [Pers.] Jens. In oats and barley two kinds of Smut can be distinguished, "naked" and "covered", in which, respectively, the spores cover the flowers or are invested by the glumes. In the very common **Naked Oat Smut**, caused by *Ustilago avenæ*, Pers., nothing is left, as a rule, but the branches of the panicle and the remains of the glumes. Sometimes the upper part of a panicle bears sound grains, while the lower part is smutted. The pest causing **Covered Oat Smut** is *Ustilago Kolleri*, Wille.

In **Barley Smut**, as in Wheat Smut, it has been shown that the spores lose their germinating power in a short time, generally after a few months. This confirms the researches of Brefeld and Hecke already mentioned, according to which the flowers are first infected, and the mycelium then penetrates into the grain, producing the disease the following year. The species causing the disease are *Ustilago nuda hordei*, Jens., and *U. tecta hordei*, Jens.

While the pests so far mentioned attack more particularly the ears or panicles, **Rye Smut**, due to *Urocystis occulta*, Rabh., characteristically appears on the younger joints of the stem, the leaf-sheaths, and the bracts, as elongated swollen streaks, which soon burst to expose the black spores. The ears of infected plants are usually stunted, and for the most part their grains do not develop. The germinal hyphæ generally pierce the epidermal cells, and spore formation takes place in that part of the tissue of the veins lying next the surface.

Maize is also damaged by one of the Ustilagineæ, **Maize Smut** (*Ustilago maydis*, Lév.). In this case the most various organs of the plant may be attacked, characteristic swellings making their appearance, under which the spores are formed. These are particularly common on the inflorescences, especially the female ones. Grains are rarely developed, but irregular pendulous swellings are seen, from which black smut escapes. More rarely Maize Smut makes its appearance on the leaves, branches of the panicles, male flowers, or even the roots. On parts so affected bladder-like swellings appear, which may attain a considerable size. The germinal hyphæ penetrate either the seedlings or the immature organs of older plants. The mycelium of the fungus produces distortions which collapse after the formation and escape of the spores.

Millet Smut may also be mentioned, caused by *Ustilago destruens*, Schlechtd.

Rusts (Uredineæ) are particularly destructive pests for grain and other crops. They infest Vascular Cryptogams as well as Phanerogams. Like Bunt and Smut they are *endophytic*, penetrating into the internal tissues of parts above ground, particularly stems and leaves. It is a familiar fact that most of them produce several kinds of spores. Besides those species which infest only one kind of host there are many others which in the course of their life-history pass from one host to another (*heterœcious* Rusts). Since de Bary proved, in 1864, partly by experimental infection, that the æcidia of barberry are a stage in the life-history of Black Rust (*Puccinia graminis*, figs. 10 and 11), much activity has been shown in working out the life-histories of other species which attack more than one kind of host. Klebahn, who has been conspicuously successful in this line of work, has recently published a large monograph on *Heterœcious Rusts.* He enumerates no less than 150 host-changing species, of which the life-histories have been experimentally determined. The spores which carry over a Rust from one vegetative period to the next are known as **teleutospores** (resting spores, fig. 11, *a*, *b*). They are extremely resistant, consist of more than one cell, possess thick brown investments, and are well able to persist through the winter, on which account they have also been called **winter spores**. They germinate in spring with the production of structures comparable to the promycelia of Bunt and Smut, and from the ends of which are abstricted special cells (**sporidia**, fig. 11, *d*) bringing about the distribution of the parasite. While some Rusts only exhibit this one kind of reproduction, the mycelium developed from the sporidia of others which have penetrated into a host may produce spores of another kind—**uredospores** (fig. 11, *d*)—which provide for propagation during the vegetative period. These develop with extreme rapidity, and cover the infected plant parts with reddish-brown swellings. These **summer spores**, as they are also called, are unicellular, invested with a thin covering, capable of extremely quick germination, and adapted for rapid spreading of the infection.

The **æcidium**, which has already been mentioned as present in some of the Uredineæ, is found below the cortex of a stem or the epidermis of a leaf. It consists of a rounded base from which a number of parallel spore-bearing cells project. The **æcidiospores** are abstricted from these. The peripheral spores are usually fused into a membranous investment, the **peridium**, which ruptures when the æcidium is ripe and liberates the underlying spores. There is no peridium in many Rusts, the æcidium being then known as a **cæoma** (e.g. Rose Rust). This spore-producing stage of Rusts is generally associated with the production of smaller fungoid aggregations, **pycnidia** or **spermogonia**, which when they occur on leaves are generally sunk in the upper side. They give rise to **pycnospores** that have lost the power of germination. In heterœcious Rusts it sometimes happens that the æcidium stage is omitted from the life-history.

Rusts give rise to various pathological modifications of the tissues of their hosts. We sometimes find cells of which the contents have been entirely absorbed by the parasite, and it may be mentioned that this partly takes up food by means of suctorial organs or **haustoria**, which project from the mycelium into the intercellular spaces and grow into the host-cells. We can then see under the microscope that the cell protoplasm shrivels up, any starch grains present are dissolved, and the chloroplasts appear as rounded yellowish bodies.

Parts which are attacked in this way usually have a yellowish, dry appearance. Pathological changes of another kind are to be seen in stems. Abnormal outgrowths of tissue resembling galls are developed, which give an irregular, deformed appearance to the diseased part. The maturity of the parasite living in the tissues generally coincides with the extreme stage of deformation, and the abnormally enlarged or hypertrophied organ dies when the parasite ceases active growth.

The appearance of Rusts is particularly favoured by long spells of damp weather. Regions exposed by their climatic position to a large amount of fog or dew are generally badly infested by these pests. Cultivated plants are rusted to a much greater extent in damp summers than during dry years.

There are at present no effective measures for exterminating Rusts. The **pickling** of seedcorn in copper sulphate solution, employed in combating many diseases of cereals, is useless in this case if the views of the Swedish investigator Eriksson are correct. He is of opinion that, as in some of the Smuts (p. 35), the parasite penetrates into the grains, and that its protoplasm forms an intimate mixture with that of the host cells, and he applies the term **mykoplasm** to this mixture. He further asserts that the haustoria of Rusts are to be found in seedcorn. The investigations of Klebahn, P. Magnus, Aderhold, and others contradict the views of Eriksson.

Some authors have recommended the breeding of **Rust-resisting** varieties of grain as a means of combating these pests, but it has unfortunately been proved in many cases that after a few years such varieties lose their power of resistance, and are once more attacked.

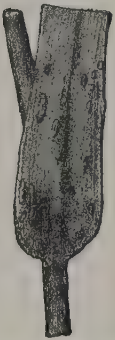
Fig. 10.—Black Rust (*Puccinia graminis*, Pers.)

Certain Rusts will now be described in detail. The most widely distributed of these is **Black Rust** (*Puccinia graminis*, Pers.), which attacks rye, oats, and sometimes barley and various kinds of wheat and wheat grasses (figs. 10 and 11). Its red-brown uredo patches closely resemble those of other species, but are less characteristic. Its groups of teleutospores, on the contrary, are easily recognized, and are chiefly to be seen on the leaf-sheaths and haulms, though they sometimes invade the ears. They occur as longitudinal, dark, black streaks on the parts affected, and these are very clearly to be distinguished from the rust-red uredo patches in which teleutospores are subsequently formed. Where the teleutospores project from the ruptured epidermis, it can clearly be seen that each of them possesses a delicate, colourless stalk. Uredospores die with the

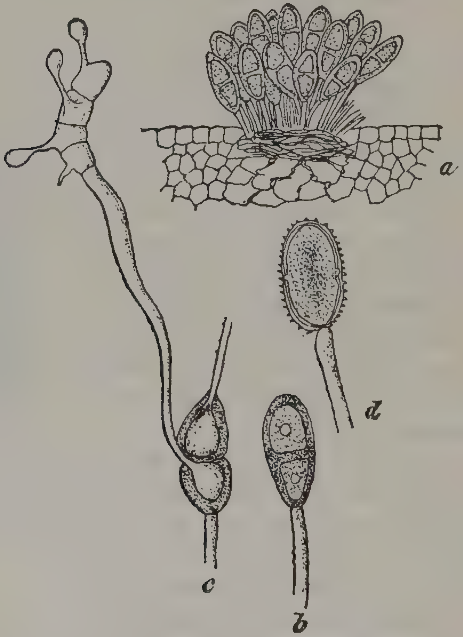

Fig. 11.—Black Rust (*Puccinia graminis*, Pers.)

a, Patch of teleutospores, seen in transverse section of a haulm of wheat. *b*, Teleutospore. *c*, Ditto germinating: four conidia being abstricted from basidia. *d*, Uredospore. (Enlarged to various scales.)

parts to which they are attached, but, as already mentioned, the teleutospores persist through the winter. They germinate in spring, producing the promycelium with sporidia to which allusion has been made. Their germinal hyphæ penetrate a second host, the barberry (pp. 38 and 10), and the æcidiospores developed in this once more carry the disease to cereals.

Yellow Rust (Frontispiece, 2 *a*) is due to the presence of *Puccinia glumarum*, Eriks. et Henn. The patches of uredospores are of yellow colour, and take the form of longitudinal streaks on the leaves. The teleutospores which are subsequently formed do not rupture the epidermis, and the diseased places are therefore less dark in colour than those of Black Rust, being of a greyish-black tint. Of cereal crops Yellow Rust only attacks rye, barley, and wheat. It is frequently found on weed grasses, such as species of Bromus. An æcidial stage has not yet been discovered.

Brown Rust (*Puccinia dispersa*, Eriks.) is recognized by its brown uredo patches, irregularly distributed on the surface of the leaves (Frontispiece, 2 *b*). As in *P. glumarum* the teleutospores are covered by the epidermis. They are grouped in dark spots and small streaks on the under side of the leaves. The æcidial stage is found on species of Anchusa. Rye is especially liable to be infested by this species, but a closely related and very similar one attacks wheat.

Crown Rust (*Puccinia coronifera avenæ*, Kleb.), only found on oats among cereals, also deserves special notice. In general appearance it closely resembles Brown Rust, but a microscopic difference is found in the presence of pointed outgrowths on the tips of the teleutospores. The æcidial stage is found on buckthorn (*Rhamnus catharticus*, L.).

Mildew is a disease to which wheat is especially liable, though it is also found on oats, barley, and many meadow grasses. It is due to the Ascomycete fungus *Erysiphe graminis*, Lév., which covers the upper sides and sheaths of the lower leaves with a thin white mycelial coating. Under the microscope dense chains of abstricted conidia can be seen (fig. 5, 1). They spread the disease during the summer, and are therefore called **summer spores.** The hyphæ cannot penetrate directly into the leaf tissue but develop minute suctorial organs **(haustoria)**, which make their way into the cells. As time goes on, the mycelium on the leaves becomes increasingly dense, and small black spots become visible. These are the second reproductive stage of the mildew, and under the microscope are recognizable as small capsules or **perithecia** (fig. 5, 2). They live through the winter and the ascospores developed in their asci disseminate the disease during the next season. They may, therefore, be called **hibernating spores**. Stubble harbouring the perithecia should be destroyed and change of cereals practised. The researches of Salmon and Marchal have shown that in the course of time adaptational races of Mildew are formed which cannot be transferred from one kind of cereal to another.

Ergot is sometimes to be found in fields of rye, wheat, and barley. The name is given to a curved dark-violet body of horny texture which replaces a grain. Technically it is known as a **sclerotium**, and is made up of compacted mycelium (p. 21). The spores of the fungus responsible for this structure (*Claviceps purpurea*, Tul.) get into the flowers and develop in the ovaries. This then elongates and its stigmas wither. In the further course of development we can observe that the lower part of the diseased ovary is completely filled with the mycelium of the parasite, the rapid growth of which has displaced the contained cavity—still clearly visible—to the tip of the young Ergot. As the fungus feeds on the tissue of the ovary, this is soon completely destroyed. A dense whitish-grey but still soft mycelium now fills the whole of the space between the glumes. On the outer side of this characteristic structure are to be seen hyphæ, from which conidia are abstricted. Before the life-history of the parasite had been properly worked out this was called *Sphacelia segetum*, Lév. As spores are formed, the fungus secretes a sticky sweetish fluid—honey-dew—which oozes in large drops from between the glumes. It contains enormous numbers of conidia. The production of these gradually ceases, and the formation of the actual Ergot commences. This begins at the base of the foundation of Sphacelia (fig. 12), a vestige of which remains as a little cap on the tip of the Ergot. This is the hibernating stage of the Claviceps, and is a hard body of dark-violet colour externally and whitish hue internally. Whether it falls on the ground at harvest or remains attached to the ear it retains the power of germination, and under favourable conditions germinates in the following spring. The details of this process are as follows (fig. 13): Relatively long whitish stalks grow out from the sclerotium, their ends enlarging into rounded heads containing the perithecia, which can be seen in a cross section as a number of regularly arranged flask-shaped depressions containing asci. The

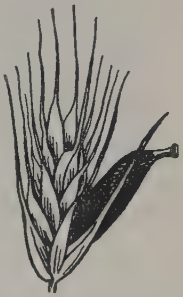

Fig. 12.—Ear with an Ergot

ripe ascospores emerge from the opening of the perithecium, and the position of this is usually indicated by a slight projection.

Apart from the injury to the cereal, for even unaffected flowers have their grain-producing power weakened, Ergot is very dangerous to human beings and stock. The use of bread made from meal in which Ergots have been ground up has frequently caused cramp in the limbs and inflammatory swelling of the joints, followed by mortification in extreme cases. Since the sixteenth century even epidemics of such disease have been recorded. On account of their deleterious action Ergots should always be carefully separated from grain before milling, and must

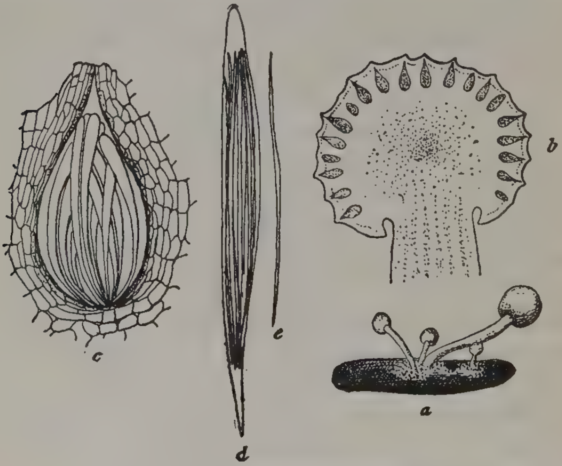

Fig. 13.—Ergot (*Claviceps purpurea*, Tul.)

a, Germinating Ergot. *b*, Longitudinal section through the head of a fruit body. *c*, Perithecium in longitudinal section. *d*, Ascus, with eight ascospores. *e*, Ascospore. (*b–e* enlarged.)

also be picked out from seed corn. It is also desirable to pick off Ergots from standing corn at an early stage.

We will now consider two diseases caused by related fungi, one attacking wheat and the other rye, which effect similar and fatal injury to the base of the haulm. The first pest, *Ophiobolus herpotrichus*, Sacc., called by Frank the **Wheat-haulm Killer**, destroys wheat plants in ear, and its presence is indicated by a blackening of the base of the haulm. The plant attacked matures prematurely, but the formation of grain is practically arrested. From the base of the haulm the mycelium grows into the roots, which blacken and die, and the life of the plant is thus ended. The hibernating form of the fungus is found in the stubble.

Leptosphæria herpotrichoides, de Not., the **Rye-haulm Breaker** of Frank, injures rye in a similar way. The haulm soon becomes white, premature maturity ensues, and the formation of grain is arrested. In June the haulms bend sharply at their bases and then break off. An entire field of rye may be destroyed in this way. As in the pest last described the mycelium does not grow into the upper parts of the host plant. Even in spring it will be seen that in young winter rye the outer leaf-sheaths are affected and the oldest leaves dead. The mycelium then spreads into the base of the haulm, and after killing its host develops small capsules which look like black dots and are the perithecial fruits of the fungus. The pest is apparently transferred from the stubble to the crop sown in winter. The pathological appearances produced have a general resemblance to those due to the Hessian Fly (p. 52).

Another disease—**False Smut**—may be mentioned here, which blackens the upper parts of cereals. Irregularly distributed black patches or small black spots appear on the epidermis of the ears—especially of the glumes, the leaves, and also the straw, giving a superficial blackish appearance. The cause is a fungus *Cladosporium herbarum*, Link, which is chiefly of saprophytic habit, and is therefore mostly to be found on corn which has been cut. It only attacks living plants when these are damaged by weather (persistent damp, summer drought) in their immature condition, or are in a prematurely dying condition. This fungus is therefore only a secondary pest. Large numbers of spores are blown about in the air and settle on the corn, quickly germinating under the favourable conditions mentioned, the mycelium penetrating and killing the host cells. The infested tissue is black, and at a later stage becomes covered with dark upright hyphæ, from which conidia are abstricted. There is also a perithecial stage, once termed *Pleospora.*

Still another fungus blackening cereals is *Helminthosporium gramineum*, Rabh., which causes **Barley Leaf Brown** or **Streak Disease.** In the middle and at the margins of green barley leaves well-marked brown streaks with light edges make their appearance, running parallel to the longitudinal veins. This pest attacks the whole of a leaf, but a related species gives rise to isolated elongated patches, not to streaks. In the former case the leaves as they die become fibrous and break up into narrow pieces. It is supposed that in these two diseases the seed corn is already infected by the spores. When it is sown, the spores germinate on the grains and the mycelium penetrates the plumules more particularly, so that all the leaves are affected.

The **Corn Leaf Spot Fungi**, which attack the leaves of cereals, may be briefly noticed in conclusion, i.e. *Leptosphæria tritici*, Pass., *Ascochyta graminicola*, Sacc., *Septoria*, *Sphærella exitialis*, Mor., and some others. The hibernating stage carries the disease into the next year, and the young cereals, especially wheat, may be destroyed in spring. The leaves, from the oldest to the youngest in succession, become yellow and shrivelled. Should the haulm continue to grow in spite of this, new leaves are formed, glumes make their appearance, and the plant matures prematurely. The perithecia of these fungi develop within the leaf tissue, and appear as very small dark spots.

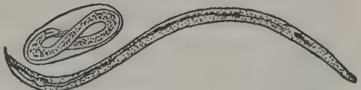

Fig. 14.—Stem Eelworm of Cereals (*Tylenchus devastatrix*, Kühn). Egg with embryo, and also a newly hatched mature worm (enlarged)

A large number of **animal parasites** also attack cereals. Among these, **Nematodes** or **Eelworms** are frequently to be seen. In spite of their insignificant size they are equipped with organs enabling them to inflict fatal injuries upon their hosts, and they possess a well-developed digestive tube. The eggs are surrounded by membranous investments, and when ripe the worm-like embryos can be seen within them. When the young are hatched they first become asexual larvæ, which, after several moults, become sexually mature within their hosts. The larvæ at first live in the soil. There are also a number of non-parasitic humus Eelworms. The parasitic forms are distinguished from these by the possession of a mouth-spine, by means of which they suck the sap of the infested plants. As regards cereal diseases, we are here more particularly concerned with the **Stem Eelworm** (*Tylenchus devastatrix* [*dipsaci*], Kühn). This minute creature attains a maximum length of 1½ mm., and is found in the leaves and stems, especially near the ground. Infested plants show a remarkable arrest in growth, and their organs are short and thick, owing to the swelling which results from the attacks of the parasites. The leaves also become deformed. The Eelworms and their eggs in various stages of development can be found in the tissues of the host plants. The young worms migrate from the organs they have killed into the soil, later on to attack new plants. J. Kühn and Ritzema Bos have proved by numerous researches that Eelworms are host-changing parasites. About fifty species of plants are at present known which present the characteristic appearances due to their attacks. Certain species, however, are specially liable to this kind of infestation.

Tylenchus devastatrix, which has been known for a long time, attacks rye and oats. It is found in the lower joints of the haulms, and the bases of the leaf-sheaths. The first symptoms of the disease make their appearance in the spring, and normal haulms are rarely formed, the infected plants scarcely attaining a greater height than 15 cm. The shoot is greatly thickened at the base, and the leaves are characterized by wavy folds.

Another member of the family, the **Wheat Eelworm** (*Tylenchus scandens*, Schneid.) causes a disease of wheat. The ears are then seen to contain dark grains, known as **peppercorns** or **purples**. These contain no endosperm, but innumerable minute Eelworms (larvæ of *T. scandens*) bound together into a hard mass. Should these peppercorns get into the ground, the contained Eelworms make their way out and attack new hosts, and this may happen after the lapse of several years, during which they retain their vitality.

Among insects causing cereal diseases may first be mentioned **Corn Thrips** (*Thrips cerealium*, Hal.). The attacks of this insect result in the falling of the lower spikelets of various cereals, nothing but the axis remaining. When the corn begins to shoot, the Thrips creep up their haulms to the leaf-sheaths from which the ears emerge. By means of their haustellate mouths and bristle-like jaws they suck the tissues and sap of the stem. About the time when rye is in flower it is almost always possible to find whole fields in which the leaf-sheaths mentioned are yellow for a length of several centimetres, and the corresponding leaves withered, the other parts of the plants remaining green and perfectly sound in spite of this. If the Thrips attack takes place before the young ears emerge from the sheaths, they develop normally and the yield of grain is not affected. Otherwise there is a reduced development of grain in the lower part of the ears.

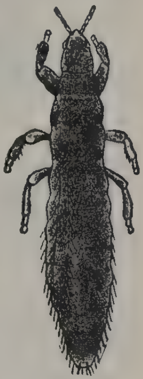
Fig. 15.—Corn Thrips (*Thrips cerealium*, Hal.). Much enlarged

A number of flies and gnats are also to be reckoned among the enemies of cereals, for their larvæ (maggots) destroy the young grains. The yield of the growth of young rye, barley, wheat, and oats may be stunted by the attacks of **Frit Flies** (*Oscinis frit*, L., and *O. pulsilla*, Mg., fig. 16). In autumn the flies (2 to 3 mm. in length) lay their eggs singly on the under sides of the leaves of young plants of the winter crop. The white maggots soon hatch out and creep down the leaf sheaths to the nodes from which they spring, and there remain. The result of the infestation depends upon the time when it takes place. The plant can very quickly be destroyed by the gnawing away of the delicate leaves in the bud, which causes the leaves to turn yellow. Should tillering have already taken place, shoots may here and there remain alive. In this case the young plants look as if suffering from Eelworms, several new shoots having been developed, thickened below like onions.

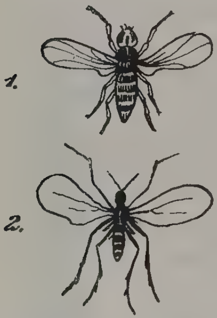

Fig. 16.—1, Frit Fly (*Oscinis frit*, L.). 2, Hessian Fly (*Cecidomyia destructor*, Say). Much enlarged

The name of this pest is said to be derived from the Swedish word *frit*, something light or worthless, having reference to the empty glumes of infested plants, in which the pupæ of the insect are to be found.

The **Hessian Fly** (*Cecidomyia destructor*, Say, fig. 16, and *C. secalina*, Lw.) is a well-known pest, which attacks the young winter or summer cereal crop at the same time as the Frit Fly. The maggots, which are of similar appearance, gnaw the young plants, and as the injuries do not heal up, the crop is easily laid by wind and rain before harvest. When the host plants decay the pupæ get into the ground, where they hibernate. The fly makes its appearance in spring.

The name of the pest was taken from Hessian mercenaries who introduced it among straw from their native country into North America, where the cornfields afterwards frequently suffered from its ravages.

In combating this pest the use of lure plants (p. 136) is recommended, so that when the winter crop is sown the eggs of the fly will already have been laid (usually in September) on plants of no value. The summer crop should be sown in good time, so that the young plants may be in a forward condition when the flies make their appearance.

The **Gout Fly** or **Ribbon-footed Corn Fly** (*Chlorops tæniopus*, Mg.) is another species attacking young cereal crops, especially wheat. Growth is retarded by the yellow maggot, which tunnels up to the ear from the first node of the haulm. Compared to normal ones, infested plants remain in leaf for a long time.

Still another wheat parasite is the **Wheat Gall-midge** (*Diplosis* [*Cecidomyia*] *tritici*, K.), an insect which has sometimes caused considerable damage. The eggs are laid in the flowers. After a few days the larvæ hatch out, and attack the parts of the flowers, especially the ovaries, so that the yield of grain is diminished. After harvest the maggots creep into the soil, where they hibernate, passing into the pupal stage the following spring. The midges emerge in July.

A considerable number of other flies are of practical interest to the farmer, but their action on the host plants presents so little that is either new or interesting to the botanist, that it is unnecessary to describe or even enumerate them here. They, and the other pests of cereals still to be dealt with in this chapter, are mostly injurious because they devour definite parts of the host. The wounds thus made are either so extensive or so numerous that it is out of the question for them to be completely healed up. Among these pests may be briefly mentioned the **Corn Sawfly** (*Cephus pygmæus*, L.), the larvæ of which bite through all the nodes of rye and wheat plants right down to the base of the haulm. Although the infested plants possess green leaves their ears are white and sterile.

A few more pests of cereals deserve notice. The **Dwarf Cicada** (*Jassus sexnotatus*, Fall.) is particularly destructive to summer crops. Like its near relatives, the Aphides, it sucks the tissues and juices of the host plants with its beak-like mouth parts. The ravages of this pest are increased by the fact that it may appear in enormous numbers, and may be almost regarded as an epidemic.

Young cereals are also attacked by certain **Surface Caterpillars**, the larvæ of the **Dart Moth** (*Agrotis segetum*, W. V.), and by the so-called **Wireworms**, the larval stage of various **Click-beetles** (*Agriotes lineatus*, L., and others). By placing bits of oilcake and potatoes as lures between the rows of young corn the wireworms can be attracted away from the crop until it is better developed and capable of offering more resistance. Similar attacks on young corn are made by the larvæ of the **Corn Ground-beetle** (*Zabrus gibbus*, F.), except that these restrict their activity to the parts above ground, i.e. leaves and stem.

Cockchafer grubs also damage young cereals by devouring their roots. Further mischief is done to corn crops by the **Field Slug** (*Limax agrestis*, L.); and the

Mole-cricket (*Gryllotalpa vulgaris*, Ltr.), which gnaws the roots, and by burrowing in the grounds uproots the plants.

Some of the **Aphides** are typical pests of cereals, sucking the sap from various organs. Their appearance is especially favoured by continued hot dry weather. We therefore find that these creatures are constantly associated with summer drought. Oats and barley suffer most from their attacks. The growth of infested plants is small, and they either turn yellow or—in oats—assume a reddish colour. The yield of grain is greatly reduced.

CHAPTER IV

AGRICULTURAL PESTS OF POTATOES—BEET AND MANGOLD—LEGUMINOUS CROPS—VEGETABLES—AND INDUSTRIAL CULTURE PLANTS

Potatoes

Here we naturally first think of the so-called **Potato Disease**, known in Europe from 1845, and apparently introduced from America. Even during the year mentioned it spread over the whole Continent, devastating potato fields far and wide. In 1861 the botanist de Bary proved it to be an infectious disease, caused by a fungus, to which he gave the name *Phytophthora infestans.* The mycelium of the parasite grows through the tissue of the potato leaf, causing it to die. The disease is externally recognizable by the appearance of dark-brown patches on the tips or edges of the leaves, usually first to be seen in July. Under the microscope it is possible to see the branching conidiophores of the fungus projecting through the stomata on the under side of the leaves. Each usually has three branches (fig. 1), from which lemon-shaped conidia are abstricted, to be carried by the wind to neighbouring plants. Within water drops, formed by dew or rain, their contents divide into six to eight parts, which escape as **swarm spores**, each possessing two flagella, enabling active swimming movements. Gradually these swarm spores reach the neighbourhood of stomata, where they germinate, the germinal hyphæ penetrating the epidermis, to begin their destructive work in the internal tissue. It is characteristic for the black disease patches, which rapidly increase in size, that—especially after damp weather—they should possess a clearly defined whitish edge from which conidiophores originate. Continuous warm damp weather greatly favours the epidemic spread of the fungus. Its discoverer, de Bary, counted about 360,000 swarm spores, all capable of spreading the infection, on a square centimetre of infected leaf.

The infestation of the fungus is not limited to the foliage of the potato plant, for the mycelium is also to be found in the tubers, causing the so-called **Phytophthora Rot**. This can be distinguished from other forms of decay by the presence of depressed discoloured spots on the surface of diseased tubers, which are clearly marked off from the sound parts. On cutting through such tubers we find brown tissue underneath the diseased spots, mostly limited to the region next the skin. To determine whether fungus mycelium is present in a diseased part of a plant is a simple matter. A bell jar lined with wet blotting paper is placed over the object (p. 15), and if Phytophthora is present its conidiophores will be found in a few days on the cut surface. By transfer of the fungus into the tuber, provision is also made for the reappearance of the disease the following year, when it is present in the sets. It can also be shown that diseased potatoes in cellars and stores infect the sound tubers. Here, too, Bordeaux mixture can be recommended as a good preventive.

Another kind of leaf disease is frequently met with in potatoes, which must be distinguished from the one just dealt with. Sorauer calls it **Drought Spot Disease**, and in America, where its attacks are much more serious than in Europe, it is known as **Early Potato Blight**. It is caused by the filamentous Oomycete fungus parasite, *Alternaria solani*, Sor. When there is persistent drought in spring, potato fields may be badly damaged. While in Phytophthora attacks the dark-brown blotches—with a whitish tinge in damp air—invade large continuous surfaces of the leaf-blades, and rapidly increase in size, the disease now under consideration gives rise to isolated blotches which die but slowly. They are irregularly distributed through the green part of the leaf, and their form is angular with some of the angles rounded off. They may be more than half a centimetre broad. As a rule, all the shoots of a plant die simultaneously. So far as known, the mycelium does not pass into the tubers.

While in this particular infestation the stem is not pathologically shortened, but generally attains the normal length, a shortened stem is characteristic of another disease of the potato, and the plants are also stunted.

The chief sign of this disease, however, is the sharp bending back of the leaves, which appear as if curled. It has therefore been called **Potato Leaf Curl.** In botanical literature the name is undoubtedly applied to a variety of pathological appearances. Some investigators are inclined to attribute the disease to unfavourable conditions in the soil. Others consider it to be caused by various fungi.

Bacteria play a large part in the destruction of potatoes. Their action has only of late years been clearly understood, thanks very largely to the pioneer work of Appel. **Black Leg** or **Potato Stem Rot** is a disease characterized by constriction of the base of the stem, usually near the ground, and an intense black-brown colour in this region. The yellowish infected leaves hang limply on the stem and quickly wither. In an advanced stage of the ailment the stems fall over, and on their upper parts black spots make their appearance, which are attacked by moulds. These spots are due to the attacks of bacteria, of which Appel has shown *Bacillus phytophthorus* to be the most important. The tubers of affected plants are not always infected by bacteria, but their growth has been greatly arrested, as their supply of nourishment is soon cut off. It often happens, however, that Black Leg results in epidemic decay, for *B. phytophthorus* is able to destroy the substance of potatoes with great energy.

The relations are quite different in **Bacterial Decay** of potatoes. Here the bacteria dissolve the cell membranes, and thus reduce the contents of the tubers to a kind of pulp. The starch grains in the cells are not affected. As in Black Leg the bacteria penetrate into the tubers from the surface of the ground. They make their entry into the tissue under the rind by means of injured spots or places weakened by the attacks of fungi. A large amount of the damage is due to *Clostridium butyricum* [*Amylobacter clostridium*], a form which generates butyric acid.

It was formerly the practice to divide the different kinds of decay in potatoes into two categories—**Wet Rot** and **Dry Rot**—though the distinction cannot be maintained in the present state of our knowledge. The names have reference to the condition of the cell sap in the diseased tissue. When this is still present, causing the tissue to be of a pulpy consistency, the name "wet rot" is applied, but when it has disappeared, and the tissue is powdery, the term "dry rot" is used.

Decay of the tubers may also be caused by certain fungi, which are extremely common in the rind, where they normally live as harmless saprophytes. If, however, they have the chance of penetrating into the flesh, they are able to set up putrefaction if the internal tissue is not sufficiently resistant.

The name **Scurf** is given to rough discoloured patches on the rind, of various sizes and irregular distribution. Microscopic examination shows that these are due to dense tangled masses of hyphæ, which only penetrate into the outer corky layers, and may even be removed by a brush. The fungus is *Rhizoctonia solani*, Kühn, which recent investigations of Lambert have shown to be identical with *Hypnochus solani*, Prill et Del.

Under certain conditions, however, this harmless inhabitant of the rind is able to set up wet and dry rot of the flesh of the tubers. Under the microscope the hyphæ can be seen traversing the tissue, mostly between the cells, of which the starch grains are quickly dissolved. The disease, as a rule, can be detected when the crop is lifted. The decay begins at one end and very rapidly reduces the tuber to a soft watery mass devoid of starch.

Under the name of **Phellomyces Rot** Frank has also described a decayed condition of potato tubers due to the fungus that gives its name to the disease, and which is also known as a harmless dweller on the rind. Here it gives rise to flecks, which look like black dots when closely examined by the naked eye. Should favourable conditions enable the fungus to penetrate the rind, its mycelium grows through the starch-containing cells. The dry rot produced by it is somewhat rare. Appel and Lambert have recently shown that the Phellomyces fungus, of which the fruiting form was previously unknown, is the well-known species *Spondylocladium atrovirens.*

Fusarium Rot also requires notice. The very common mould which causes it not only attacks the parts above ground, but also leads to dry rot in the tubers. The investigations of E. Smith and Swingle have shown that *F. oxysporum* is particularly destructive in this way. It is interesting to notice that in this disease the mycelium chiefly grows in the vessels, and in affected tubers the ring of bundles near the rind is distinctly blackened. Appel has observed a similar appearance in a disease due to bacteria (**Bacterial Ring Disease**).

Much less damage is caused by **Bristle Mould**, *Stysanus stemonites*, [Pers.] Corda, a fungus frequently found on the surface of stored potatoes. It may easily be recognized by the fact that its tufts of conidia project from the rind or from injured places like the bristles from an unshaven chin. It was shown by Appel and Bruck that this fungus is sometimes parasitic in the internal tissues of tubers.

The potato possesses a special protection against the entry of agents of decay in its great powers of regeneration. In very many cases it offers extremely well-marked resistance to the spread of parasites by forming cork layers (wound cork or callus) between the sound and diseased tissue.

Besides the different kinds of Rot, potatoes sometimes present a mottled appearance, the cause of which has not yet been discovered. On cutting through such tubers, iron-brown or grey-brown patches will frequently be seen, which are present when the crop is lifted. The disease is not transmitted by the sets, and appears to be due to special soil conditions.

Potato Scab is known to the farmer as a disease marked by the presence of superficial flat bark-like patches on the tubers, while sometimes their entire surface may be affected. Opinions differ as to the cause of the disease, some attributing it to bacteria, others to certain lower fungi (*Oospora* spp.). The scabs may be prominent, flat, or depressed.

[**Wart Disease** or **Black Scab** is a notifiable disease caused by the fungus *Chrysophlyctis endobiotica*, Schilb., of which the classificatory position is doubtful. Eriksson places it in the Chytridiaceæ, while others regard it as a Myxomycete. The disease is externally recognizable by the presence of black warts in the neighbourhood of the "eyes". These enlarge, extend, and fuse together into corrugated masses. Microscopic examination shows that the pest is unicellular. The contents of the rounded cell body may break up into motile **swarm spores**, which spread the disease, or may pass into a resting stage, developing a firm investment. The **resting spores** thus formed persist through the winter.]

It has also been shown that **animal pests** may be concerned with the decay of potato tubers, as, for example, certain Eelworms, apparently belonging to *Tylenchus devastatrix*, which causes stem disease in cereals and clover. A tuber affected by **Eelworm Rot** looks superficially like one attacked by Phytophthora. The rind is here and there pitted and discoloured, and on cutting through the potato, brown spots will be seen under the pits. Microscopic examination, however, will show that mycelium is absent, and will reveal the presence of clumps of Eelworms, carrying on their destructive mining work.

The **Bulb Mite** (*Rhizoglyphus echinopus*) also helps to bring about potato decay, and it is particularly harmful because the wounds it makes in the flesh of the tubers do not heal so readily as those caused by other pests, thus affording opportunity for the attacks of bacteria causing decomposition.

Seed potatoes are often found to be tunnelled by **Wireworms**, the larvæ of certain **Click-beetles** (*Agriotes* and *Athous* spp.). The **Surface Caterpillars** of the **Turnip Moth** (*Agrotis segetum*, W. V.) bore large holes in seed potatoes, and hinder the development of the crop by gnawing off the young shoots.

Beet and Mangold

The diseases of beet and mangold constitute one of the sections of plant pathology where the least progress has been made. In spite of the great importance of these plants to the farmer and the connected industries (sugar, &c.), it has so far not proved possible to determine with certainty the causes of their most harmful diseases. Fresh organisms are constantly being discovered upon diseased specimens, but it is difficult to say which of these are the real pests and actual sources of disease.

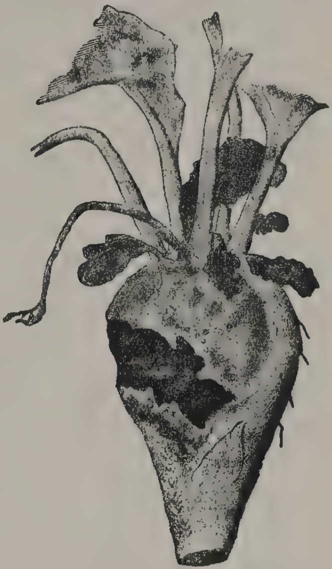

Fig. 17.—Beet and Mangold Rot (*Phoma betæ*, Frk.). A diseased root of sugar beet

One of these diseases, **Beet and Mangold Rot** (*Phoma betæ*, Frk., fig. 17), is very destructive to fields of the crops under consideration. Especially when the late summer is associated with continuous drought the leaves begin to blacken. First the tender heart leaves are affected, and then the disease gradually extends to the older ones. If a plant has lost its large leaves before the beginning of the drought it is able to offer a relatively strong resistance to the attacks of certain pests, for the reduction in transpired water automatically diminishes the amount absorbed from the soil. But when leaves are present which are so much injured as to have lost the power of transpiration, a lack of correlation follows between the normal absorption of water from the soil and that transpired, the latter being reduced by the death of the leaves which normally effect it. A beet or mangold thus weakened can offer but little resistance to the attacks of parasites.

Connected with Beet and Mangold Rot a **Dry Rot** of the root of the plant affected can usually be recognized. In the first stage of the disease recovery is still possible—as in various potato diseases—by the formation of layers of cork which divide the sound tissue from that which is injured. But if this does not take place the process of decay spreads until the plant is completely destroyed. Both in the diseased heart leaves, and also in the tissues of the root, the mycelium of the fungus *Phoma betæ*, Frk., is found in most cases, and sometimes also that of another fungus, *Fusarium beticola*, Frk. On the diseased parts of the plant small black dots are to be seen, these being capsules, from which slimy masses of spores escape. They are the pycnidial fruit of Phoma. The same pest is at times a saprophyte on the dead leaves of beet and mangold, and may also give rise to blotches on living leaves. These are round patches about the size of a threepenny piece, bright tobacco-brown in colour, with a darker margin. The Fusarium covers the diseased parts with white mouldy patches, resembling those caused by the Fusarium of potato. Under the microscope it is easy to recognize the conidiophores with their characteristic multicellular crescentic conidia.

By the aid of inoculation experiments it has been demonstrated that both the fungi just described are capable of setting up beet and mangold rot, but similar experiments with the bacteria occasionally found in diseased plants have failed.

Wounded places on different parts of the body, especially those made by surface caterpillars, greatly favour the entry of the parasites. Even those beets which are only partly attacked by rot suffer a great reduction in their sugar content.

Girdle Scab of sugar beet is another incompletely understood disease. Here there is formation of cork on the outside of the root, small longitudinal and transverse cracks making their appearance, especially in the thick central region, while the top and tail are but seldom affected. In contrast with Beet Rot the inside of the root usually remains sound. Sometimes, however, the scabbed region forms trough-like depressions projecting into the underlying flesh. There is a remarkably strong resemblance to the scab diseases of potatoes already described.

F. Krüger, who has lately made a detailed study of Girdle Scab, believes that "the scabby places anatomically correspond to wounds healed with or without the formation of callus". It is so far unknown what organisms make the wounds, but some of the lower fungi (*Oospora* spp.) and certain small white thread-shaped worms (*Enchytræids*) have been suspected.

The **Damping Off** of beet and mangold seedlings may here be mentioned. After young seedlings have unfolded their cotyledons, brownish or blackish patches appear in the tissues of the hypocotyl and extend down into the root, giving a "black-legged" appearance. Seedlings which are not vigorous enough to outgrow the disease soon die, especially when the weather and soil conditions are unfavourable. Under favourable circumstances there may be complete recovery, but even late into July brown discolorations and constrictions due to the disease may be seen underneath the rosette of leaves.

The latest researches of L. Peters group three different diseases under the name of **Root Blight** (Wurzelbrand), all giving rise to similar pathological changes. By careful inoculation Peters was able to induce disease with pure cultures of three species of fungus—*Phoma betæ* Frk., *Pythium de Baryanum*, Hesse, and a species belonging to the genus *Aphanomyces* (Saprolegnieæ). Hiltner and Peters had previously demonstrated that in these diseases anything tending to weaken the young plants—apart from the actual infection—has an important influence. They showed, for example, that when harvesting or the subsequent operations had to be carried on in very wet weather or under other unfavourable conditions, weakening chemical substances (oxalates) were generated in the crop.

The name **Bacterial Gumming** of beet and mangold ("tail rot") is given to a disease in which, in late summer, the narrow "tail" of the root begins to shrivel and take on a greyish-black discoloration that extends into the middle of the root. The affected tissue shrinks, and sticky sap exudes from its vessels. In stored roots the gumming and dry rot continue to go on, and, as they can also extend to sound specimens, are exceedingly destructive. A bacterial form *Bacillus betæ*, able to decompose cane sugar, has been isolated from diseased roots, but the conditions determining its migration from the soil to attack the crop have not been determined. It is certain, however, that the disease appears earliest in dry summers.

Another disease, caused by the fungus *Sclerotinia Libertiana*, Fkl., is to be found in cellars and stores, and may even assume an epidemic character. It was proved by de Bary that the mycelium of this fungus excretes a ferment which kills the outer cell layers of the root. After this the fungus lives saprophytically on the dead tissue, while by solution of the cell walls the whole interior of the root becomes a soft watery mass. During this process the external mycelium, which looks like a covering of cotton wool, thickens, the individual hyphæ fusing together into hard structures, which resemble flat cakes or sometimes spheres in appearance. These hard structures, which have a black colour externally, are known to the botanist as **sclerotia** (p. 21). In this case we speak of **Sclerotium Disease.** The mycelial covering, with its sclerotia, and the remains of the superficial tissue of the root, make up a kind of external skin, which can be pulled off like a cap from the internal pulp.

In the course of a few months the sclerotia, both those which get into the soil and those which remain among the remains of the roots, develop cup-like fruits (fig. 7). The ascospores which these produce again distribute the disease rapidly and with certainty. As in stores and cellars the parasite easily travels from one root to another, the spread of the infection is easily intelligible.

Violet Root Rot of beet and mangold is a less important disease due to the fungus *Rhizoctonia violacea*, Tul. It appears only on the roots, which it covers with purple-red warts, spreading from the narrow part upwards, and causing decay. It is usually restricted to a few plants, and first makes its appearance in late summer.

There are also leaf diseases, which by reducing assimilation diminish the storage of reserve materials, and thus do considerable damage. Among these may first be mentioned **Beet and Mangold Rust** (*Uromyces betæ*, Tul.). In spring the familiar red-yellow **cluster cups** or **æcidia** are to be seen on the leaf-stalks. During summer the **æcidiospores** infect the leaf-blades, and the groups of **summer spores** are soon seen as reddish spots, to be succeeded later by the brownish **winter spores.** This must not be confused with **Beet Leaf Blotch**, caused by *Cercospora beticola*, Sacc. Here small round patches make their appearance on the leaves, their inner parts gradually becoming transparent, and their edges red and swollen. These spots may fuse together. As a rule the infected leaves die off quickly. Microscopic examination soon shows the presence of the characteristic tailed spores of the fungus, which are multicellular and thickened at one end.

Another pest attacking the leaves of beet and mangold is **False Mildew** (*Peronospora Schachtii*, Fkl.), which, like most diseases of the kind, is easily to be distinguished by mould-like patches, situated in this case on the under side of the leaves. In damp years the fungus may be extremely abundant, and the development of the roots may then be affected very seriously. As the parasite chiefly attacks the heart leaves, the name **Heart Rot** is sometimes given to it. [This name is otherwise applied in Britain.]

Among **animal parasites** attacking beet first place may be given to the **Beet Eelworm** (*Heterodera Schachtii*, A. Schm.), which causes **Beet Sickness**. This results in great losses to beet and also mangold culture, and always makes its appearance when the crop is grown for many years successively in the same field. The worm is closely related to the Tylenchus described under diseases of cereals, and like this spends its larval stage in the soil. For the purpose of reproduction these minute thread-like creatures make their way into the host plants, which include not only beet and mangold, but some forty other species, mostly Crucifers and leguminous plants. They perforate the epidermis of the roots, and attach themselves firmly to the cortex. They then lose their worm-like shape and assume a stouter form, at the same time causing swelling of the part attacked. The general appearance and size vary according to sex.

The male emerges from the larval skin in order to fertilize the female. The fertilized females increase considerably in size, leading to rupture of the cortex, so that their bodies project at the exterior. From the beginning of June onwards we find these pregnant females everywhere on the roots, until they attain complete maturity in autumn. Their minute bodies, which stud the lateral roots like pearls, then become thick-walled brood capsules, in which some hundreds of eggs are to be found (fig. 18). From these several generations of Eelworms may arise, even apparently in the same year. As in species of Tylenchus, the mouth-spine characteristic of parasitic Nematodes can be recognized.

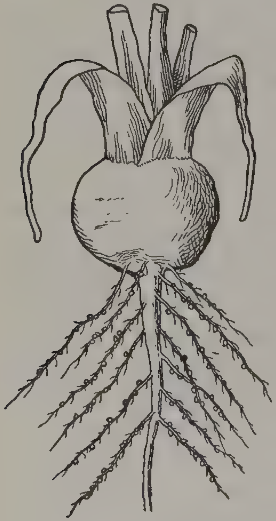

Fig. 18.—Beet attacked by Eelworms

The disease gives rise to well-marked outward symptoms in the crop. An infected plant grows less rapidly than a sound one, and has a more celery-like appearance. In an extreme case it may even happen that, after a few feeble leaves have developed, further growth ceases, the root failing to enlarge. On the other hand, it may also happen that in spite of marked infestation the plant develops fairly well, and in this case the plant had become vigorous enough to offer resistance before it was attacked to any extent.

In coping with beet sickness of the soil the employment of a rational rotation of crops is the measure most to be recommended. Excellent results have also been obtained by planting several successive crops of **Lure plants** (summer rape) in the course of one year. The roots of these attract the Eelworms in enormous numbers, and the plants must be destroyed when the Heterodera begins to enter the reproductive stage.

We may mention, in passing, the **Root-knot Disease** of cucumbers [and tomatoes] caused by *Heterodera radicicola*, Greef. The characteristic root galls due to the attacks of this parasite are represented in fig. 19.

Among other animal foes of beet and mangold may be the larvæ of the **Beet and Mangold Fly** (*Anthomyia conformis*, Fall.), which tunnel in the leaves of the crop and completely destroy them. As in cereals and potatoes, great damage may also be done by **Cockchafer Grubs**, **Surface Caterpillars**, and **Wireworms**.

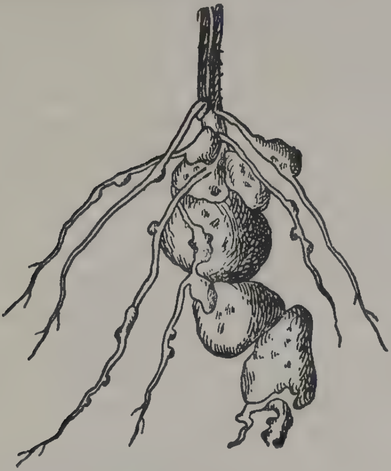

Fig. 19.—Root Galls of *Heterodera radicicola*, Greef, on Cucumber. After Berkeley

Other pests are the **Tortoise Beetle** (*Cassida nebulosa*, L.), the **Beet Carrion Beetle** (*Silpha atrata*, L.), the **Turnip Sawfly** (*Athalia spinarum*, Fbr.), and the **Black Aphis** (*Aphis papaveris*, L.), all of which attack the leaves.

Leguminous Crops

Leguminous plants are not free from **Rusts**, though the damage done to them by these fungi is inconsiderable. On the leaves of certain species we find roundish spots (containing **summer spores**) irregularly distributed, followed by blackish swellings (masses of **winter spores**). The stems and leaf stalks are the parts mostly attacked. They turn yellow and soon fall off. The development of plants is very injuriously affected should the infestation take place during the period of growth.

The various rusts of Leguminosæ belong to the genus *Uromyces*. The most interesting species is **Pea Rust** (*U. pisi*, de By.), which is a heterœcious form. The **æcidial stage** is found on species of Spurge (*Euphorbia*), from which the **æcidiospores** are carried by the wind to pea plants, their germinal hyphæ entering the leaves by the stomata. Actively growing mycelium is soon formed in the mesophyll, and summer spores are developed.

Other species of Uromyces, closely resembling Pea Rust in the nature of their attacks and their life-histories, are: **Clover Rust** (*U. trifolii*, Wint.), **Vetch Rust** (*U. orobi*, Wtr.), which also attacks lentils and horse beans, **Bean Rust** (*U. phaseolorum*, Tul.), and **Lupine Rust** (*U. anthyllidis*, Schröt.).

Among **Mildews** may first be mentioned the **False Mildew** of Vetches (*Peronospora viciæ*, Berk.), also found on lentils, peas, and beans. The first symptom of disease consists in a bleaching of the vetch stem. This is followed by the appearance of the bright-grey mould characteristic of the Peronosporeæ on the under sides of the leaves. Microscopic examination shows that this consists of conidiophores bearing characteristic conidia. The parasite is only very harmful in continued damp warm weather. A very similar species as regards appearance and habit is *P. trifoliorum*, de By., which attacks clovers and lucerne.

True Mildew (*Erysiphe Martii*, Lév.) infests the leaves of various leguminous plants, and is most prevalent in late summer. It attacks clovers, vetches, lupines, and sainfoin, giving a whitish appearance to considerable tracts of such crops. As in Corn Mildew the hyphæ of the fungus are seen on the epidermis of green parts, and penetrate into the cells by suctorial processes. The wide distribution of the pest is not remarkable, for it is found on a large number of other plants (various Crucifers, Urticaceæ, Spiræa, &c.), which easily spread the infection.

Violet Root Rot (*Rhizoctonia violacea*, Tul.) attacks clover and lucerne, and is also found on beet, mangold, potatoes, serradella, and some other plants. It kills the roots, covering them with a felt-like investment of violet colour, which induces decay in the underlying parts. The infestation is externally visible in July. Attacked plants first turn yellow, and then the leaves and stems wither.

Two stem diseases may be mentioned in passing. One of these, **Clover Stem Scorch**, is caused by *Glœosporium caulincola*, Krchn., marked by the presence of elongated patches on the stem, dark in colour with a lighter margin, and penetrating deeply into the tissues. Here the fungus develops with production of small blackish pustules, external to which the tissues of the host are destroyed.

Black Stem Spot is caused by the fungus *Cryptosporium leptostromiforme*, Kühn, which infests the stems of lupines, and is generally found as a harmless parasite or as a saprophyte on dead plants in almost every lupine field. Under some conditions, however, it infests the tissues of the stem in healthy living plants—sometimes before flowering—stunting and killing them. The disease is externally recognizable by the presence of black oval patches on a light ground within the cortex of the stem. These are the fruits of the fungus.

Among blotch diseases caused by fungi may first be mentioned **Bean-pod Blotch Disease**, which attacks the pods of dwarf beans and kidney beans, and is caused by *Glœosporium Lindemuthianum*, Sacc. et Mgn. On the unripe green pods, especially near the ground, may be seen brown sunken blotches with swollen lobate margins (fig. 20). Sometimes several of these blotches fuse together into a patch more than 1 cm. broad. The fungus may penetrate the wall of the pod, attacking and damaging the seeds, but not weakening their power of germination. When this takes place, the fungus attacks the cotyledons, and the disease is carried into a fresh year. Spores settling on young plants quickly develop new masses of mycelium, by which the disease is rapidly spread.

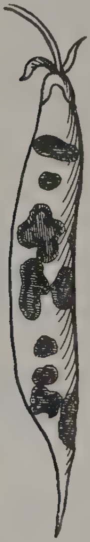

Fig. 20. — Bean-pod Blotch Disease (*Glœosporium Lindemuthianum*, Sacc. et Mgn.)

Pea Spot (*Ascochyta pisi*, Lib.) is another disease of the kind affecting the pods, leaves, and stems. Blotches appear on the pods as in the last-described infestation, but here they are of a bright-brown colour with dark-brown margins. As in the bean blotches the fungus penetrates the wall of the pod and attacks the seeds, which though much damaged retain the power of germination and transmit the disease to the seedlings. Attacked plants usually turn yellow, though their tips sometimes remain green. The blotches already described make their appearance on the yellow parts. As in the last disease, infection is spread not only by the seeds, but also by spore capsules which have hibernated on the straw.

Clover Leaf Spot is due to *Pseudopeziza trifolii*, Fkl. It is met with in early summer in the form of brownish spots with yellowish edges, which soon dry up. The spore fruits develop in the middle of these as minute dots, and hibernate on fallen leaves, the ascospores escaping the next year to spread the disease.

Clover Sclerotinia (*Sclerotinia trifoliorum*, Eriks.) may even appear in an epidemic form, and cause great destruction. Of late years it has been common. As it closely resembles *S. Libertiana*, Fkl., described under Beet and Mangold Disease (p. 67) in the nature of its attack and life-history, a detailed account is here unnecessary. Spores which settle on the fairly young leaves of various clovers quickly develop a strong mycelium in the mesophyll, and this spreads continuously through the tissues of the host. The lower parts of the stem are chiefly attacked. Ultimately only remains are left of the vessels and epidermis, upon which a white exposed mycelium develops and produces sclerotia (p. 21). The following spring these sclerotia give rise to apothecia, and the ejected ascospores germinate on clover in damp weather.

Clover is also attacked by phanerogamous parasites. One of these, **Clover Dodder** (*Cuscuta trifolii*, Bab.), twines in a close spiral round the stem of its host from the ground upwards (fig. 21), crippling and killing its victim (p. 111). Groups of reddish-white flowers are developed on the tangled thread-like stems, which are rose-coloured. Seeds are abundantly set, and it is by these that the parasite is distributed. Besides destroying all remains of Dodder on the stubble, dressing with sulphate of potash is recommended, and also covering the ground with chaff or similar material, so as to smother the parasite. Dodder also attacks vetches and lupines.

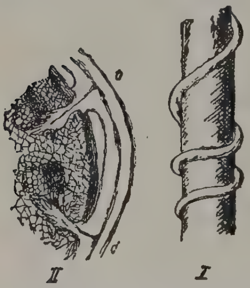

Fig. 21.—Dodder (*Cuscuta*)

I, Twining stem. II, Transverse section through a host stem, showing the haustoria of the parasite penetrating the tissues (*d*, *d*).

The **Lesser Broom-rape** (*Orobanche minor*, Stck.) is another higher parasite, devoid of chlorophyll, which attacks clover (fig. 22). It attaches itself to the roots, extracting nutritive substances from them by means of suctorial processes. In some parts of Germany this pest has destroyed whole fields of clover. Frank states that in Baden one to five plants of broom-rape have been found on 1 sq. ft. of ground. Its wide distribution is easily explained by the vast numbers of seeds which are produced. There may be as many as 1500 of these in a single capsule, and an individual plant bears thirty capsules or more. In dealing with this parasite it is recommended that it be pulled up with its host plant before seeds are set, and it may perhaps be necessary to change the crop on infested fields. In Baden these measures have often been enforced by police regulations.

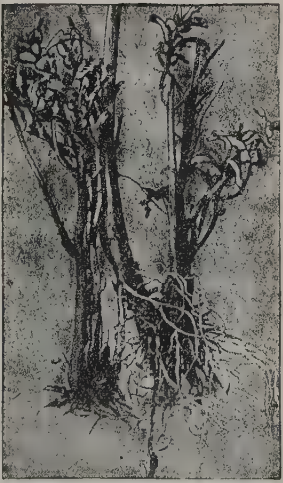

Fig. 22.—Broom-rape (*Orobanche*)

Among **animal pests** damaging leguminous plants prominence must be given to the two species of **Eelworm** already mentioned—*Heterodera Schachtii*, A. Schm. (p. 69) and *Tylenchus devastatrix*, Kühn (especially in clover and lucerne). Of importance also are some Flies (the **Lupine Fly**, *Anthomyia funesta*, Kühn); Moths (**Crescent Pea Moth**, *Grapholitha dorsana*, F., **Fawn-coloured Pea Moth**, *G. nebritana*, Treitsch.; **Silver-Y Moth**, *Plusia gamma*, L.; **Pea Moth**, *Mamestra pisi*, L.); Aphides (**Pea-leaf Aphis**, *Siphonophora ulmariæ*, Schk.; **Bean-leaf Aphis**, *Aphis papaveris*, F.). Among Beetles may particularly be mentioned species of *Bruchus* which attack the ripe seeds of peas and beans (**Seed Beetles**). Round holes about 2 mm. in diameter may be seen in such seeds, closed by little covers while the beetles are still inside, but open when these have made their escape.

CRUCIFEROUS CROPS

Among diseases attacking Crucifers cultivated for agricultural purposes may first be mentioned **Finger-and-toe**, **Anbury**, or **Clubroot**, caused by the myxomycete (slime fungus) *Plasmodiophora brassicæ*, Wor. The naked protoplasmic masses (**plasmodia**) of this pest get into the root cells of cabbage (also rape, turnip [fig. 23], cress, &c.), and their presence stimulates the tissues to abnormal growth. The result is the development of large tumour-like swellings on the roots, suggesting clumsy fingers, or else a number of small round swellings that lie like strings of pearls along the branch roots. The abnormal growths are especially well marked on the main root. At first they are white in colour and of firm fleshy consistency, and at this stage microscopic examination will show the nucleated plasmodia of the parasite within the tissue cells (p. 19), later on to be replaced by masses of spores. The diseased roots gradually decay, and the Plasmodiophora spores thus get into the soil. Actively moving **swarm cells** escape from these, but later on lose their flagella, and enter a host plant to become plasmodia. The growth of diseased plants is soon retarded; they take on a sickly appearance and their leaves easily wither. Rational rotation of crops is recommended as a means of com-

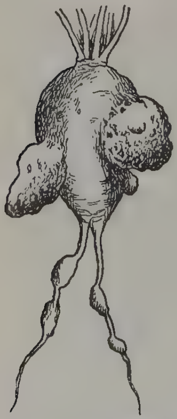

Fig. 23.—Finger-and-toe (*Plasmodiophora brassicæ*, Wor.) in a Turnip

bating this disease, and good results have been obtained by disinfecting the soil with quicklime before planting.

Damping Off of young cabbage seedlings is due to a simply organized fungus, *Olpidium brassicæ*, Wor., the appearance of which is favoured by damp weather.

Bacterial Diseases are very common among cabbages and other cruciferous vegetables. They closely resemble, in nature and effect, the bacterioses of potatoes, beet, and mangold. As in these we can here distinguish between **Scab Diseases** affecting the superficial tissues and **Rot**, which either pulverizes the internal tissue (Dry Rot) or converts it into a pulpy mass (Wet Rot). Such changes are usually brought about by some of the bacterial species which are always present in the soil as a result of favourable conditions, among which the most important are weather, humidity, and various characters of the soil. It is typical for one group of these diseases that the vascular bundles should be blackened, as may be seen when infested parts are cut open. A great variety of bacterial diseases of the kind broadly known as **Black** and **Brown Rot** not only attack adult plants, but also very young ones. Of this nature is the **Black Shank** of cruciferous seedlings, of which the first indication is the appearance of brownish to black patches below the attachment of the cotyledons. This is followed by decay of the tissues. Attacks of this nature damage young seedlings wholesale.

White Rust of rape, cabbage, and turnip is caused by *Cystopus candidus*, Lév., one of the lower fungi. White thickenings are to be seen on the stems and inflorescences, and variously shaped white patches on the leaves. A white powder escapes when the epidermis covering these is ruptured. Active growth is promoted by the irritation of the various tissues due to the presence of the parasite, and results in characteristic malformations of the stem, axes of the inflorescences, and particularly of the flowers, of which the various parts are remarkably thickened. The leaves become yellow in the neighbourhood of the diseased patches, where formation of spores is going on, and premature death follows. As in the Phytophthora Disease of potato the germinating conidia give rise to **swarm spores**, by which the disease is spread. Special **resting spores** are also formed, which, after hibernating for several months, infect host plants in the spring. Cystopus is a very common form, and is met with on all sorts of wild Crucifers, being, for instance, a constant parasite of shepherd's purse (*Capsella Bursa-pastoris*, L.).

Lettuce Mildew (*Bremia lactucæ*, Reg.) is closely related to White Rust. The attacked parts or spots become clothed with a white mycelial layer from which the conidiophores project. [This pest is conveniently considered here, though lettuce is a Composite, not a Crucifer.]

The host plants of White Rust are also attacked by **False Mildew** (*Peronospora parasitica*, de By.). On the under side of a diseased leaf will be seen a number of patches of whitish mould, and on the upper side a corresponding number of yellowish patches. By means of the microscope we can see very clearly the branched conidiophores of the fungus projecting through the stomata of the lower epidermis. As in White Rust, **resting spores** are formed, which remain dormant during the winter.

There are two particularly harmful parasitic fungi which attack rape—*Sporidesmium exitiosum*, Kühn, and *Sclerotinia Libertiana*, Fkl. The black hyphæ of the former are especially common on unripe fruits, as well as other green parts, causing these to die. According to the investigations of Julius Kühn, who first described the disease, the yield of seed is greatly reduced. The fungus hibernates under the snow on parts of the host plants which have fallen to the ground. The conidia are able to germinate quickly, but can also remain dormant for a long time. Their germination is greatly favoured by damp.

Sclerotinia Libertiana, Fkl., has already been described as a parasite of beet and mangold (p. 67). Although the disease is rare, it is extremely harmful when it attacks a rape crop. The nature of the infestation and the life-history of the fungus have been sufficiently described under beet and mangold diseases.

Rape and cabbage plants are injured by certain insects. The maggots of the **Cabbage-root Fly** (*Anthomyia radicum*, L.) cause abnormal development as a result of the tunnels they gnaw out. Other pests are various caterpillars, e.g. those of the **White Butterflies** (*Pieris* spp.), the **Cabbage Moth** (*Mamestra brassicæ*, L.), **Vegetable Moth** (*M. oleracea*, L.), and the **Crucifer Midge** (*Cecidomyia brassicæ*, Wtz.), of which the larvæ appear in very large numbers in the fruits of rape, spoiling the seeds. There are also the **Cabbage Flea-beetle** (*Haltica oleracea*, L.), the **Rape Flea-beetle** (*Psylliodes chrysocephalus*, L.), and various **Weevils.**

It may be mentioned in passing that a **False Mildew** (*Peronospora spinaciæ*, Laub.) is tolerably common on spinach. [Spinach is a Chenopod, not a Crucifer.]

ASPARAGUS

Asparagus Rust (*Puccinia asparagi*, DC.) is very harmful in asparagus fields, its teleutospores hibernating on the stems.

Plants are also killed by the maggots of the **Asparagus Fly** (*Trypeta fulminans*, Mg.), which excavate vertical burrows in the tissues of the stem.

ONION

Sclerotium Disease (*Sclerotinia cepæ*, Lib.) damages cooking onions, causing them to become mouldy. It is not only observable in fields, but also in stored onions. A white, flocky mycelium is first observed, frequently associated with mouse-grey patches of "Botrytis" (p. 104). Both develop sclerotia. The frequent association of Sclerotinia and Botrytis gave rise to the view that they are simply two stages in the life-history of one and the same fungus.

A **False Mildew** (*Peronospora Schleideniana*, Ung.) may also be harmful to the onion crop, especially to young spring onions. The parasite attacks the parts above ground, its mycelium developing rapidly within them, and giving rise to tree-like conidiophores.

Among **animal pests** may be mentioned once more the **Tylenchus Eelworm**, and also the **Onion Fly** (*Anthomyia antiqua*, Mg.), of which the maggots do much damage to the young crop.

HOPS

Hop Mildew (*Sphærotheca castagnei*, Lév.) forms a white covering to the stem, leaves, and cones. If the scales of the last are very badly attacked, the disease may diminish the crop. Infection readily takes place, for the parasite is found on many other plants (composites, rosaceous species, &c.

Mention may also be made of **Black Blight** of hops, a fungus (*Capnodium salicinum*, Mont.) which forms a black investment on the living plant, and appears to live saprophytically. By shading the host it greatly retards the process of assimilation. Goethe long ago tried to explain its appearance.

The hop is also largely attacked by Aphides, caterpillars, and certain beetles. Of these last the most harmful is the **Hop Beetle** (*Plinthus porcatus*, Pz.), the larvæ of which tunnel the rootstock, thus generally causing the death of the plant.

FLAX

Flax Rust (*Melampsora lini*, Wtr.) is an extremely harmful parasite for this crop. The patches of rust-coloured **summer spores** are chiefly found on the younger leaves, while large irregular black blotches containing **winter spores** are to be seen on the stem and older leaves.

CHAPTER V

PLANT DISEASES—FRUIT TREES

When we examine the figures as to the amount of fruit annually exported from and imported into Germany we get results which ought to make us feel ashamed.

The large extent to which we depend on foreign countries may be illustrated by the figures for 1903. In that year fruit was exported to the value of £605,750, while the value for the imported fruit was £4,279,800, i.e. about seven times as great.

One very important means of combating this undesirable state of things so as to increase our fruit harvest, consists in employing improved measures to reduce the number of pests, for these destroy a considerable part of the annual yield. A thorough inspection of imported fruit in our ports would also give good results by preventing the entry of pests (e.g. the **San José Scale**—*Aspidiotus perniciosus*—from America).

To rationally cope with diseases it is above all things necessary to understand their nature, whether caused by non-living influences or due to pests.

Under the conditions of **temperature** which seriously damage fruit trees the action of **frost** plays the most important part. Allusion has already been made to the very thorough investigations which have been made by Sorauer in this direction, and which we shall employ as a basis for our description. Other results of a fundamental kind will be given in the next chapter (p. 98).

Frost is not always able completely to destroy plants, and its attacks more often result in local injuries. First as to the **leaves**. On the edges of these, and also irregularly distributed on their upper surfaces, grey-brown patches are produced, which in apple and pear later on assume a dark black colour. They lie in the middle of the sound green tissue. These are the places where freezing has at times taken place during May frosts, and ice been formed. The epidermal cells covering such spots are dead and dry, and the internal green tissue is often shrivelled. Upon a single tree it is very often possible to find all possible transitions between leaves which are only slightly blotched and those which have been completely destroyed by frost.

The **flowers** are frequently exposed to the action of frost. Late spring frosts injure the stigmas and stamens of just-opening flowers, blighting them completely. Not infrequently the other parts of the tree are quite untouched. Young **shoots** may also be killed by frost, and the dying off of their tips is particularly characteristic. This may frequently be observed in the Morello cherry. Here also the young expanding shoots are not yet able to withstand May frosts. Leaves and flowers then give a favourable opportunity for the attacks of a grey-yellow **Cushion Mould** (*Monilia fructigena*, p. 94).

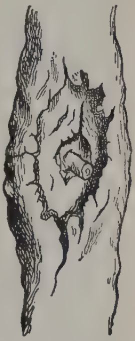
Fig. 24.—Frost Scab

Wood and **bark** are exposed to a great many kinds of injury by frost. Under the name **Bark Scorch** may be included all cases where variously sized pieces of bark are killed. We can frequently find, for instance, dried up pieces of bark easily separable from the wood, and reaching a length of more than a metre. Smaller injured patches of the same nature, chiefly round eyes and buds, are termed **frost cracks.** The name **Frost Scab** is given to small projections on the bark of young apple and pear trees, which have a scaly scabby appearance owing to the presence of numerous longitudinal and transverse cracks (fig. 24). By the application of artificial cold to healthy twigs of fruit trees Sorauer was able to induce the same appearances as those seen in frost crack. The injuries so far described are mostly due to spring and late summer frosts, but the effect of winter frosts may also be observed. As may be very clearly seen in the trunks of cherry trees, these cause rupture of the bark right down to the wood. Such **Bark Cracks** usually prove the best places for the inception of wood diseases caused by the entry of fungi. It is characteristic of such cracks that the middle of the wound is not closed, but simply walled over by the bark. The same thing takes place in **Bark Scorch**, and places where the tissues have been killed right down to the cambium and sap-wood become surrounded by zones of material developed from their sound edges, so that the tree is protected from disease and death. In what is called **Frost Canker** a number of such zones are formed, which surround the injury like a series of terraces, of which the outermost is always the youngest. The zones below it are usually killed by frost, as their tissues possess but little power of resistance. These injuries assume the most remarkable forms, and a distinction is drawn between **open** and **closed** frost canker, in which, respectively, a large central area or a minute crack remains uncovered by the growths from the edge. A fungus (*Nectria ditissima*, Tul.) of which the rose-red pustules beset the swollen margins of frost cankers, has been regarded by various investigators as the cause of the swellings. There can, however, be no doubt that this fungus, which sometimes appears as a pest (p. 118), here plays only a secondary part.

Gumming is a disease frequently observed in trees bearing stone fruit, especially cherries and peaches. It is caused by chemical and ferment action, by which wood, cambium, and bark are converted into a gummy substance. Various external agents, such as wounds when the sap is actively flowing, and the fungus *Clasterosporium carpophilum*, [Lév.] Ad., are able to initiate the chemical changes involved. When a tree "gums", to use the term employed by Aderhold, an investigator of the disease, a sticky fluid hardening into knobs exudes from the bark. Such pearl-like drops are not uncommon upon the fruits.

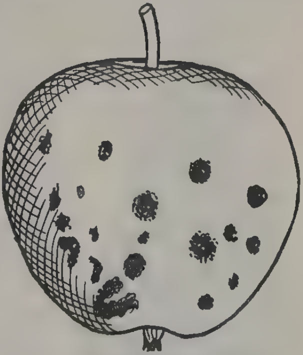

Fig. 25.—Apple Scab (*Fusicladium dendriticum*, Fkl.)

We now come to diseases caused by parasitic fungi. **Apple Scab** (*Fusicladium dendriticum*, Fkl., fig. 25), which attacks the most various parts, greatly damages apple and pear trees. Its spores are easily dispersed by rain and wind and quickly germinate. When present on unripe fruit it gives rise to irregularly distributed surface spots, round, black, and flocky, with white serrated edges. These gradually increase in size, and cork is formed in their centres. They often fuse together into patches 3 to 5 mm. in diameter. During winter they spread rapidly in stored fruit, and give a very unpleasing appearance. Sorauer investigated the penetration of the mycelium into the epidermis and subjacent tissues, and found that it forms a dense mass in the former, gradually assuming the appearance of a crust cut off from below by the formation of cork in the parenchyma. Sorauer also found that black spots on apple leaves are due to the presence of Fusicladium in its conidia-producing stage. Aderhold proved that this fungus is synonymous with *Venturia inæqualis*, Ad., the ascus-bearing fruit of which he found on apple leaves that persisted through the winter. **Pear Scab** is a similar disease due to *Fusicladium pyrinum*, Fkl. (fig. 26), which injures leaves and fruit in the same way as Apple Scab. It also attacks one-year-old shoots, with the formation of boil-like pustules. The ends of the shoots often die and the terminal buds dry up. Aderhold proved this pest to be equivalent to *Venturia pyrina*, Ad., of which the ascus-bearing fruits are found on fallen leaves, as in Apple Scab.

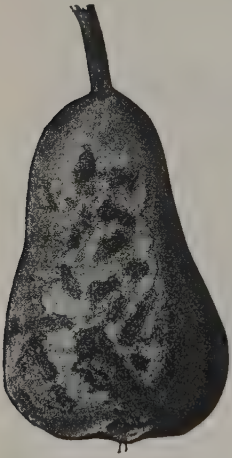
Fig. 26.—Pear Scab (*Fusicladium pyrinum*, Fkl.)

Another harmful fungus is *Septoria pyricola*, Desm., which causes black patches on pear leaves, that later assume a reddish and finally a whitish colour. On the under side of their dry central part the encapsuled conidial form of the fungus is found. There is apparently a connection between this parasite and the fungus *Septoria nigerrima*, Fkl., of which the ascus-bearing fruits are found on fallen pear leaves.

Among other **Leaf Spot Diseases** of rosaceous fruit trees may be mentioned **Leaf Brown** (*Stigmatea mespili*, Sor.) and **White Spot** (*Sphærella bellona*, Sacc.).

Trellis Rust (Frontispiece, 3) is a particularly harmful pest to the pear and some of the other rosaceous fruits. It is a member of the interesting family of Rusts, which have already been so often mentioned. It is also one of the heterœcious Uredineæ (p. 38), and is seen on pear leaves as large patches of a foxy colour. The spermogonia of the fungus (*Ræstelia cancellata*, Reb.) first appear as small red spots on the upper side of the leaf, to be followed by cluster cups on the under side, these being visible to the naked eye. They consist of a series of flask-shaped spore-receptacles placed side by side and covered with white caps. They also occur on the fruits. Sometimes the disease is so acute in character that the development of the whole tree is checked, or the crop rendered very scanty.

The special host for the **winter spores** is savin (*Juniperus Sabina*, L.), but other species of juniper, e.g. *Juniperus virginiana*, L., so frequently planted in gardens and parks, may harbour the teleutospores. In this stage the fungus is known as *Gymnosporangium Sabinæ*, Dicks. It is found on the twigs in the form of red-brown swellings which break through the bark. These are of jelly-like consistency, and the teleutospores are developed in them. As in other Rust diseases (e.g. in cereals) it is desirable to remove the danger-bringing hosts of the last stage from the neighbourhood of fruit trees.

Among other heterœcious Rusts which are harmful to fruit trees must be mentioned *Cronartium ribicolum*, Dietr., which causes **Blister Rust**. The uredospores and teleutospores are to be found on the leaves of gooseberry, as well as on red and black currants. At first small yellowish spots are seen on the under side of the leaves, which become larger patches in the form of slender conical outgrowths, in which teleutospores are developed. The æcidial stage makes its appearance on the bark of Weymouth pine (*Pinus Strobus*), as shown by Klebahn, and is named **Weymouth Pine Rust** (*Peridermium strobi*, Kleb.).

Among the diseases of gooseberries may also be mentioned **Gooseberry Leaf Mildew** (*Microsphæra grossulariæ*, Lév.) and **American Gooseberry Mildew** (*Sphærotheca mors-uvæ*, [Schwein.] Berk. et Curt.). While the former fungus has long been known in Europe, and is comparatively harmless, the latter was introduced from America, first appearing in Ireland in 1900, and spreading to Great Britain and the Continent, where it has proved itself the most serious of all diseases of the gooseberry. It has been known in Germany since 1903. Its life-history is similar to that of Corn Mildew (p. 43). Leaves, shoots, and fruits exhibit mycelial patches which are at first white and of delicate texture, afterwards assuming the form of thick, felted, coffee-coloured investments. The parts attacked become stunted and deformed.

Cherry Leaf Scorch (*Gnomonia erythrostoma*, Auersw.) attacks sweet cherries during the summer, causing spots about 1 cm. in diameter to appear on the surface of the leaves. They are at first distinguished from healthy tissue by being of a lighter colour, but they gradually turn yellowish, and the leaves begin to wither. When in autumn the sound leaves fall off, the diseased ones remain on the tree, their stalks curling over the twigs. In this condition they may persist through the winter, and are still present when the new leaves unfold. The danger of these becoming infected lies in the fact that the fungus is harboured by the dry blades and stalks of the dead leaves. It is an Ascomycete, and our knowledge of the disease is more particularly due to the investigations of Frank.

Plum Leaf Blister (fig. 27) is caused by a parasitic fungus (*Polystigma rubrum*, Tul.) closely allied to the one just described. Red patches which appear on the leaves in summer are the seat of the disease, and their red colour is caused by the mycelium of the fungus growing in the mesophyll. A swelling is thus produced, although the epidermis remains uninjured. These swellings, which give the disease spots a fleshy appearance, are mostly found on the under side of the leaves. We can also see here small darkish spots, which are the openings of spermogonia. Ascus-bearing fruits develop on the fallen leaves, and in this way the disease is carried on into the following year. At the beginning of the summer the ascospores make their escape, and quickly begin to germinate on the plum leaves. When large numbers of blisters appear on the leaves the assimilatory power of the tree is greatly reduced.

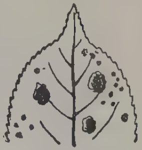

Fig. 27.—Plum Leaf with Red Patches caused by *Polystigma rubrum*, Tul.

Pocket Disease of plums and damsons, causing distortion of the fruit, is caused by an ascomycete fungus, *Exoascus* [*Taphrina*] *pruni*, Fkl., of which the asci are not contained in receptacles but project freely from the epidermis of the host, as shown in fig. 4. The deformation is caused by the spores of the parasite, which attack the still unripe green fruits, causing them to assume the form of elongated flattened "pockets", pointed at the lower end. These gradually take on an ochre-yellow colour, have a very nasty taste, and soon fall off. The disease is particularly harmful, for the mycelium penetrates into the branches, and makes it perennial. The infected twigs swell up, and assume a curved appearance, assuming the form of what are known as "witches' brooms".

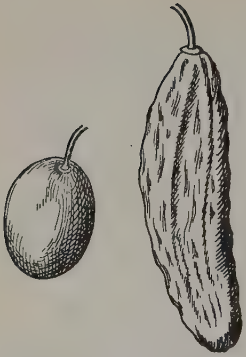

Fig. 28.—Pocket Disease of Plum (left, a young sound fruit; right, a diseased one)

Exoascus cerasi, Fkl., a near relative of the last fungus, is the cause of the true **Witches' Brooms** on the cherry tree (fig. 29). They are particularly

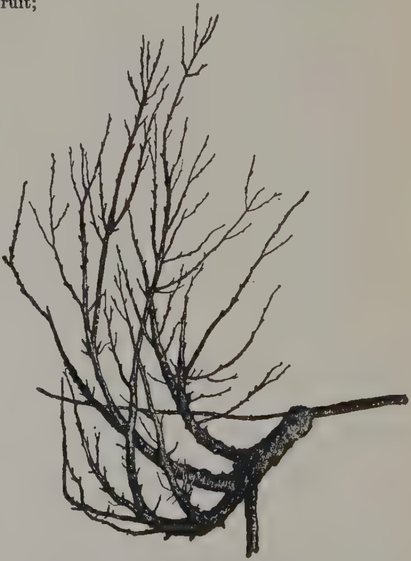

Fig. 29.—Witches' Broom of Cherry, due to *Exoascus cerasi*, Fkl.

noticeable when the tree is in full bloom, on account of their green covering of leaves, absent from normal branches. Their short and thick twigs make a sort of nest, from which the mycelium passes into the leaves, where a whitish tinge on the under side indicates the presence of asci.

Peach Leaf Curl (*cloque du pêcher*) is a serious disease of peach trees due to *Exoascus deformans*, Berk. (fig. 30), and it begins to make its appearance on the leaves in spring. Their under sides become concave, and they exhibit patches of whitish bloom, due to the presence of asci. In this disease also the mycelium penetrates far into the twigs. As a result it is able to persist through the winter, making its way into the leaf stalks and leaves the following spring, and causing the familiar "curl".

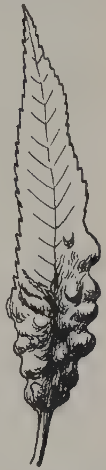

Fig. 30.—Peach Leaf Curl (*Exoascus deformans*, Berk.)

Certain fungoid diseases of hazel, such as **Hazel Leaf Spot**, are fairly common, and indirectly interfere with the production of fruit. Here again we find spots of various size on the surfaces of the leaves, grey-brown in colour with a black margin. They are partly due to a *Phyllosticta*, partly to a *Marsonia.*

Strawberry Leaf Spot is caused by a fungus (*Sphærella fragariæ*, Sacc.) closely related to Phyllosticta. The blotches are specially distinguished by their narrow red borders. Pycnidia are developed in them.

Moulds are not unknown to the fruit grower. It has already been mentioned that *Monilia fructigena* (or *cinerea*, Pers.) readily attacks fruit which has been exposed to the deleterious action of frost. Peaches, apples, pears, and plums are all liable to infection. In damp years especially the parts affected turn brown or even black, and are seen to be covered with thick, rounded, brownish-grey patches of mould. Sorauer also observed that this fungus kills cherry flowers, by actively growing through the flower stalk, calyx, and young ovary. At present this species of Monilia is only known with certainty in the conidial stage, but it may possibly be equivalent to *Sclerotinia cerasi*, though such a view is not free from objection.

(Species of *Polyporus*, wood-destroying fungi, may often be observed on fruit trees. For details see p. 119.)

Among **animal pests** attacking fruit trees the Hemiptera may first be mentioned. Various **Aphides (plant lice)** make their appearance on cherry, apple, and peach trees, infesting the under sides of the leaves, which become concave. Sometimes a leaf may be completely rolled up from tip to base. The leaf tissue usually remains normal during aphis attack, but sometimes swells up or hypertrophies.

Periods of severe drought and heat are particularly favourable to this kind of infestation. At such times the pests suck more sap, and they also propagate more rapidly.

The **Woolly Aphis** or **Apple Root Louse** (*Schizoneura lanigera*, Hausm.) is one of the greatest enemies to the culture of apple trees. It belongs to the Hemiptera, and lives mostly in the bark, causing cankerous swellings. In fig. 31 the insect and the results of its activity are represented. The latter is recognizable by the white woolly patches on the bark. Under these the Aphides are to be found in lines or groups. They are of a brownish-red colour, scarcely more than 2 mm. in length. A red fluid exudes on crushing them, and this serves as a means of identification. There are wingless as well as winged individuals, the latter usually beginning to fly at the end of the summer. The white woolly substance is excreted by the pest, and serves as a protection. By means of its beak-like mouth-parts the Aphis penetrates to the cambium, causing abnormal cell development, with the production of swollen outgrowths on the twig. The abnormal tissue is a soft, spongy parenchyma, which ruptures and dies in the colder part of the year. Many of the Aphis communities are thus destroyed. A good many of them, however, find refuge and shelter during the winter in the edges and clefts of the wounds. The infestation thus goes on from year to year, causing first the death of individual branches, and ultimately of the trees.

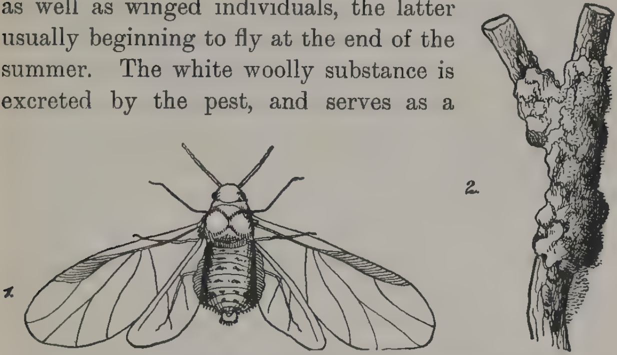

Fig. 31.—1, Winged Individual of Woolly Aphis (*Schizoneura lanigera*, Hausm.). 2, Twig of Apple Tree attacked by the Pest

The parasite also causes swellings on the roots of apple trees. The damage done every year to fruit culture is considerable, and the powers of rapid propagation possessed by the pest have much to do with this. During the summer a new generation is produced almost every fortnight.

The larvæ of certain midges tunnel in unripe pears and cause them to fall off early, e.g. those of the **Pear Midge**, *Diplosis pyrivora*, Riley [= *Cecidomyia nigra*, Meig., and *C. pyricola*, Nörd.], and the **Black Pear Midge**, *Sciara pyri*, Schm. Their small white maggots are found in the completely destroyed cores of pears. The **Pear-leaf Blister Mite**, *Eriophyes pyri*, Nalepa [= *Phytoptus pyri*, Pag.] lives within the leaves and causes the tissues to swell into "galls".

The maggots of the **Cherry Fly** (*Spilographa cerasi*, F.) burrow in ripe cherries and spoil them. Apples have also their animal parasites, by which their value is diminished. Worm-eaten specimens are often to be found, either while still on the tree or after they have fallen. The mischief is done by the maggots of the **Codlin Moth** (*Carpocapsa pomonella*, L.), which also attack pears.

The **Apple-blossom Weevil** (*Anthonomus pomorum*, L.) is another pest of both apple and pear. It lays its eggs in the flower buds, and the quickly hatching grubs prevent the flowers from developing normally. Examination of the infested buds, which remain closed, shows later on the holes from which the adult beetles make their escape.

The caterpillars of a great many butterflies and moths attack the leaves and buds of fruit trees and other deciduous trees, effecting various kinds of damage. Only a few can here be named—**Mottled Umber Moth** (*Hibernaria defoliaria*, Cl.), **Winter Moth** (*Cheimatobia brumata*, L.), **Brown-tail Moth** (*Euproctis chrysorrhœa*, L.), **Lackey Moth** (*Bombyx neustria*, L.), **Gipsy Moth** (*Liparis dispar*, Sch.), and **Black-veined White** (*Aporia cratægi*, L.).

CHAPTER VI

PLANT DISEASES—VINES

The diseases and infestations of the VINE constitute one of the most interesting parts of our science. The great epidemics caused by animal and plant pests during last century, and the considerable loss thus sustained by vine growers, directed general attention to the subject. In Germany vineyards occupy about 296,000 ac., and their annual produce is worth over 4 million pounds sterling, so that great interest clearly attaches to vine pests. The vine grower, however, has not only to reckon with pests, but must also protect himself against other adverse influences.

Chlorosis is a disease which makes its appearance in smaller and larger vine-growing districts. Affected vines are close together, and their leaves on unfolding are of a yellowish-green colour, or even quite yellow. These usually die in the course of the summer, while the grapes remain very small and become shrivelled. If the disease recurs on the same stock year after year the wood gradually dies and the plant ultimately perishes. The causes of this disease are not at present clearly understood.. Frank regards chlorosis as a symptom of various diseases of the root or disturbance of its functions. In his opinion the presence of impermeable layers of soil at a certain depth interferes with the supply of oxygen, or the non-porous nature of the subsoil prevents the water from draining away, so that—aided by fungi (e.g. *Dematophora necatrix*, R. Htg.)—it causes the roots to decay. It must also be emphasized that chlorotic vines are especially common on highly calcareous soils. In dealing with it, drainage and thorough aeration of the soil are especially recommended.

Red Leaf is another disease causing discoloration, due to abnormal conditions in the soil (soil exhaustion, extreme dryness). While in chlorosis the leaves are yellow when they unfold, the change in colour here takes place in the course of the summer in previously normal leaves. The margins, and parts adjoining the stalk, exhibit patches of a dark-red colour—sometimes passing into grey or black—sharply marked off from the green parts. We are here concerned with the well-known change which precedes the death of leaves, and in which a red pigment is formed in the cell sap. An entire vineyard may sometimes suffer. Parasites have nothing to do with this disease, as in Red Spot and Grape Rot (p. 102), which produce similar discoloration.

Action of Frost.—It has long been well known that the poorer in sap parts of plants are, so much the greater is the resistance they offer to frost (e.g. seeds). Juicy parts, on the contrary, including those in a condition of active growth, are only too easily killed by severe frost. Vines succumb to this agent when they have not attained complete vegetative development owing to a cold summer followed by a short autumn. Spring frosts are particularly harmful to the young foliage, the production of which has been favoured by a spell of warm dry weather. One result of such spring frosts is **Frost Canker**, which appears in the form of well-marked swellings on the vine stocks, due to injury of the cambium, and resulting in the death of the stem when they are very large.

As a protection against frost, where vines are grown on a small scale, good results have been obtained by covering with such material as sacking, straw, leaves, moss, &c. **Smudge fires** have proved very useful in the case of vineyards, as devised by Lemström (p. 134).

Wind may cause brownish patches on the leaf blades, especially adjoining their margins. As A. Hansen proved experimentally with the aid of a blowing apparatus, a moderate wind, if constant, quickly causes the edges of vine leaves to turn first brown and then black.

The action of **Lightning** has also been studied in vineyards. In one case it was observed that a spot struck could be seen from a distance as a circular patch. All the 335 vines within this area showed a number of tile-red patches on their leaves; and in the tissues of the stem, especially the cambium, a reddish discoloration was noticeable. The grapes on these plants dried up (Frank).

Much more harmful than the elemental influences described are the host of animal and plant pests which attack vines.

Among these, two diseases, both known to the vine grower as "Mildew", may be particularly mentioned, one true and the other false. The true or **Powdery Vine Mildew** has been known in Europe since 1845, where its starting-point was England. In the years succeeding it spread with great rapidity into most vine-growing European countries and destroyed the prosperity of thousands of persons. Hugo von Mohl proved in 1851 that the exceedingly minute spores of the fungus are blown by the wind on to the vine leaves, where they germinate very rapidly. A mealy white mycelium covers the cuticle of the leaf, attached by lobed adhesive disks, from which sac-like suctorial processes penetrate the epidermis. This and the neighbouring cells are quickly killed, brown patches making their appearance on the infected leaves and fruit. The leaves then soon wither, and the grapes, which at the time of the main infection are still hard, burst and dry up.

The conidia are abstricted from conidiophores of the white mycelium (fig. 6), and do not require specially moist conditions for their development. They can germinate at once, and spread the disease with extraordinary rapidity. The name *Oïdium Tuckeri*, Berk., was given to this conidial stage, the first to be known. After many years it was discovered that the perithecial form of Oïdium is one of the Erysipheæ, *Uncinula spiralis*, Berk. et Curt., a fungus found on wild vines in North America. A particularly good means of dealing with this pest consists in dusting the affected parts with flowers of sulphur.

The means of gaining the mastery over this undesirable vineyard infestation had hardly been discovered when a new fungoid parasite began to make its way into vine-growing European countries. This **Downy Vine Mildew** or **Leaf-fall Disease** appears at the beginning of summer in the form of white mouldy patches on the under sides of the leaves (Frontispiece, 1), with corresponding patches varying from yellow to brown in colour on the upper sides. The leaves dry up and the grapes also cease to develop, being thus deprived of the necessary nourishment. If the fungus also attacks the flowers and unripe fruit it causes **Leather Berry Disease** in the latter. Grey patches appear on the wrinkled grapes, which turn brown and easily fall off (fig. 32). The life-history of the pest, *Plasmopara* [*Peronospora*] *viticola*, de By., is as follows: The white, copiously branched mycelium does not—like true Mildew—simply cling to the epidermis, but penetrates into the interior of the vine leaves, completely absorbing the cell contents. When the fungus reaches the reproductive stage, tufts of branching conidiophores, from which ovoid **conidia** are abstricted, grow through the stomata on the under side of the leaf. The conidia effect the rapid distribution of the pest. They are carried away by the wind, germinating when next rain or dew falls, six to eight **swarm spores** escaping from each of them to send their germinal hyphæ into the epidermal cells (much as in the closely related Phytophthora, p. 55). Plasmopara also reproduces sexually, with formation of **oospores**. These are able to hibernate in fallen leaves and fruit, and hence a necessary preventive measure in dealing with this pest consists in burning such material in autumn. The best cure consists in several sprayings with mixtures of copper sulphate and slaked lime. In a vine-

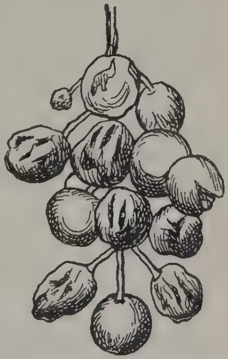

Fig. 32.—Leather Berry (*Plasmopara viticola*, de By.) in the Vine

growing area good results in coping with Plasmopara can only be expected when concerted action is taken, preferably supported by the State.

Among the remaining fungoid diseases of the vine, Red Leaf Spot and Grape Rot are of special importance. **Red Leaf Spot** causes red patches, sometimes with a lighter margin, especially common on the leaves of varieties bearing purple grapes. The distribution of the spots on the leaf blades is extremely characteristic and cannot be mistaken for Red Leaf. Müller-Thurgau proved the infestation to be due to the fungus *Pseudopeziza tracheïphila*, the mycelium of which grows into the vessels. Its perithecia ripen on the fallen leaves, and it is a good thing to burn these in the autumn. As a preventive measure spraying with mixtures of copper sulphate and slaked lime has good results.

Grape Rot appears on all green parts of the vine, causing black patches in the spring, which assume a whitish tint in the middle owing to the drying up and sinking in of tissue. The black margin projects to some extent. The tendrils and young grapes are most liable to attack. The disease is caused by *Sphaceloma ampelinum* de By. [= *Glœosporium ampelophagum*], Sacc., of which the spore-producing parts break through the epidermis, while its mycelium grows through the internal tissues. The diseased wood should be cut back and burnt, and all parts of the plant painted with a 10- to 15-per-cent aqueous solution of ferrous sulphate.

The name **Vine Black Rot** is given to a disease which is externally very similar to the last one described, as dark patches with black margins appear on all the young parts of the plant. Here, however, the diseased spots on the leaves do not become perforated in the middle, and the pycnidia of a fungus appear on them in the form of black dots. The patches are at first confined to the leaves, but afterwards appear on the grapes, which shrivel at an early stage. The parasite concerned is *Læstadia* [*Physalospora*] *Bidwellii*, Ellis, which also has a perithecial stage, to be found on the fallen grapes. The ascopores formed in these readily transmit the disease to healthy vines. In Europe this disease is of no great importance, and it has not so far been noticed in Germany. In America, however, it is one of the most serious infestations of the vine. As in most vine diseases, different varieties resist the attack of the fungus to a varying extent.

Vine White Rot, due to *Coniothyrium* [*Phoma*] *diplodiella*, Sacc., resembles the last disease in producing pycnidia, except that these and their conidia are larger. The infestation is especially prevalent in Hungary, Upper Italy, and America. The fungus attacks more particularly the grapes and their stalks, causing dark-edged patches with pustule-like pycnidia on the former.

Another Pyrenomycete fungus deserving notice is *Acladium interaneum*, Thüm., which causes one kind of **Leather Berry Disease.** Some of the grapes take on a brownish colour, are wrinkled on the under side, and possess a very thick leathery skin. This infestation, particularly common in the Tyrol, must not be confounded with Leaf-fall Disease (p. 100), which in many districts is also called Leather Berry.

Another fungus belonging to the same group is *Dematophora necatrix*, R. Htg., and this is also a very harmful pest, popularly known as **White Root Rot**. It causes decay of the root, and ultimately the death of the vine, though this may take several years to accomplish. The parasite is distributed underground from one plant to another. Our knowledge of the life-history of this form is due to Robert Hartig, who has more recently discovered that after a mould-like mycelium has spread over the roots sclerotia-like swellings develop in the clefts of the bark, where they are arranged almost regularly. Brush-shaped conidiophores are produced by them here and there. Other plants cultivated in the neighbourhood of vines, such as fruit trees, potatoes, and beans, are also attacked by the parasite. The parts of affected plants above ground present almost exactly the appearances described for cases of disturbance of nutrition. They are stunted, and the wrinkled yellow leaves easily fall off.

Another vine parasite belonging to the Sclerotineæ is **Vine Sclerotinia** (*Sclerotinia fuckeliana*, de By.) of which the conidial form was formerly described as a distinct species, under the name of *Botrytis cinerea*, Pers. (**Wine Mould**). When grapes attacked by this are used for making wine, this becomes tasteless and insipid. The white to grey-brown mycelium is everywhere found on vines, grapes, and all sorts of decaying substances, and ultimately produces sclerotia. I have never succeeded in producing apothecia from these, but have often seen the conidial stage break out from them. It is also to be noted that this parasite attacks plants which are not very vigorous, especially those which have been in any way weakened and thus rendered less capable of resistance. In consequence it frequently happens that the stems and fruit are attacked at the same time not only by Botrytis but also by other saprophytic moulds.

We now turn to **animal pests**, among which especial interest attaches to the **Vine Louse** (*Phylloxera vastatrix*, Planch.). In 1865 this was first observed in the vineyards of Provence. The botanist Planchon, whose task it was to find out why so many vines died, discovered that the roots are the actual seat of the disease. Yellow knot-like swellings are to be seen on the tips of the little branches of roots which have not yet become woody (fig. 33, 3). These are caused by the sucking of the wingless larvæ, which goes on during the summer. Without being fertilized they lay several hundred eggs, which quickly develop. The rapid distribution of the Vine Louse becomes intelligible when the fact is known that in a single summer there may be eight successive generations. Before winter these pests creep into the earth, and begin egg laying once more when the weather becomes warm the following year. In August, however, some of them

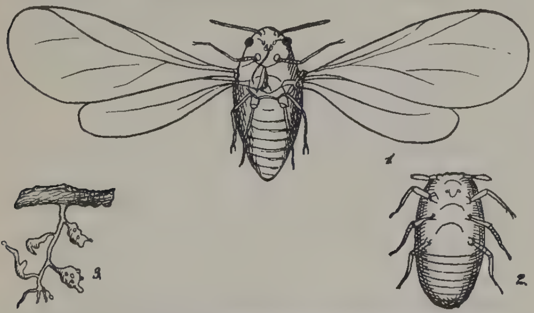

Fig. 33.—1, Winged Vine Louse (*Phylloxera vastatrix*, Planch.). 2, Wingless do. 3, Swellings on the Vine Roots

emerge at the surface and pass into a winged stage (fig. 33, 1), so that they are able to migrate to other places and carry on there their destructive work. Although these winged forms are sexless, the eggs they produce hatch out into wingless males and females. The "winter eggs" resulting from the sexual union of these are laid by the female in sheltered places on the vines, usually under the bark. Here they pass the winter, and the following spring they hatch out into larvæ (mother larvæ), with which a new cycle of development begins.

The Vine Louse has proved itself particularly destructive in France, Italy, and Austria-Hungary, but has also made its unwelcome appearance on almost every German vine-growing district. During the years of worst infestation (1880–9) this insignificant insect caused a loss to France of 560 million pounds sterling. Two-fifths of the 6,175,000 ac. under vines were attacked by the parasite.

The serious losses due to this infestation have led in Germany to state regulations for dealing with it, and in the vine-growing districts special Government officials are charged with its detection. An infected place must at once be reported, and private persons are not allowed to deal with it unaided. The method adopted consists in burning infested plants and those in their neighbourhood. The soil is then disinfected by means of petroleum and carbon bisulphide, and all articles likely to harbour the pest are cleansed with paraffin. Particular care is taken by means of these measures to interpose a safety zone between healthy and infested areas. The exportation of vines from an attacked district is also forbidden.

The Vine Louse has made its way into Europe from

America, where, in the course of time, wild vines have become extremely resistant to its attacks. This knowledge is made use of in France by importing American vines—which are protected by their bark from the Vine Louse—and grafting the native cultivated varieties upon them. The stock not only nourishes the graft, but forms a support resisting the attacks of the parasite, thus proving an excellent protection.

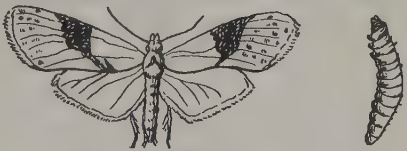

Fig. 34.—*Conchylis ambiguella*, Hbn.

A number of **moths** are vine pests, of which only three will be mentioned here, all very similar in their mode of life, and the nature of the damage they do. *Conchylis ambiguella*, Hbn., has two broods. The first set of caterpillars appear during the flowering season in June, spinning over the flowers and buds and devouring the parts of the former. After pupation the moths appear, and smaller caterpillars are hatched from their eggs. They are to be found from mid-August till September, and attack the ripening grapes, fastening them together by threads. Mould soon settles on the damaged fruit and brings about its decay. In the following spring the first brood of moths escape from the hibernated pupæ.

The **Vine Cross-moth** (*Grapholitha botrana*, Schffn.), which when at rest displays a mark like a St. Andrew's cross on its back, also produces two broods in the year. It is found in the warmer regions, especially the Pfalz in Germany.

The third moth is *Tortrix Pilleriana*, Schffn., which is on the wing in July and August. The female lays her eggs on the upper side of the leaves, which are covered by a web and devoured by the active caterpillars. Enclosed in greyish-white cocoons, situated in the bark or on the vine props, they remain dormant through the winter, and resume their destructive work the following spring. Pupation again takes place in July. This pest is particularly destructive in France, Hungary, and Baden, and the Pfalz in Germany.

The **Vine-leaf Gall Mite** (*Phytoptus vitis*, Land.) gives rise to a whitish felt, which afterwards becomes brownish red, on the under side of the leaves. The upper side curves downwards, and a number of bladder-like humps appear upon it, usually associated with a reddish discoloration. A leaf thus attacked has a completely deformed appearance.

Vines are also subject to infestation by **Beetles**, among which the **Vine Leaf-roller** (*Rynchites betuleti*, Fbr.) may particularly be mentioned. After this has gnawed through young parts of the vine, and devoured flowers and buds, the female bites through the petioles and twigs, thus causing the leaves to wither. She then rolls up the leaves into the form of cigars, her eggs are laid within these cases, and the minute larvæ that hatch out from them feed upon the leaf tissue.

Among other beetles attacking vine leaves may be mentioned the **Vine Weevil** (*Otiorhynchus sulcatus*, Fbr.), **Vine Leaf-borer** (*Bromius vitis*, Fbr.), and **Vine Ground Beetle** (*Anomala ænea*, Deg.). The larvæ of Bromus tunnel in the leaves.

CHAPTER VII

PLANT DISEASES—GARDENS AND DECIDUOUS WOODS

Among the very numerous pests of deciduous woods, parks, and gardens only a selection of the most notorious can here be mentioned.

Rose Mildew (*Sphærotheca pannosa*, [Wllr.] Lév.) is a very injurious parasite of the rose. Its mycelium covers the leaves and twigs of roses as a delicate mealy investment, from which lobed haustoria penetrate the epidermal cells, without getting into the underlying tissue. The fungus is particularly harmful to young shoots, checking the growth of buds and young leaves, and causing them to die. It can also destroy the flower buds.

During the whole summer the mould abstricts vertical rows of conidia from its short conidiophores (cp. Corn Mildew, fig. 5, 1). As in most Mildew diseases a good remedy is powdering with flowers of sulphur.

Rose Rust (*Phragmidium subcorticium*, Schr.), a disease of both wild and cultivated roses, is particularly common —like rose mould—during damp summers. The rust-red patches of **uredospores** appear on the under sides of the leaves, and are quickly succeeded by the black aggregations of **teleutospores**. The life-history of the fungus has been worked out in detail by Frank and J. Müller (1886). According to them the æcidial stage can be found all through the year on the under sides of the leaves and their stalks, except from December to March. **Æcidia** also appear in the flower region (calyx and peduncle), causing deformations. It is always advised to collect or cut off the diseased parts, but unfortunately this is only a half-measure, for the mycelium of the æcidial stage hibernates in the bark and wood of the stem. The æcidiospores germinate with ease on the leaves, and their germinal hyphæ grow through the stomata into the internal tissues. The uredospore and teleutospore stages follow in due course.

Rose Galls are characteristic, thick, rounded bodies, found on the leaves and twigs of both wild and cultivated roses, and caused by the female of the **Rose Gall Fly** (*Rhodites rosæ*, L.), which perforates the plant with her ovipositor and lays her eggs in the wounds. They are usually surrounded by a mossy investment of tangled green or red fibres, and are popularly known under the names of old man's beard and bedeguars.

In dealing with Corn Rusts two cases were mentioned where a second host is found in a woody deciduous plant. In the case of Black Rust this is the barberry, while in Crown Rust it is one of the buckthorns (*Rhamnus catharticus* or *R. Frangula*). In **Barberry Rust** the æcidial stage of *Puccinia graminis* is found on the under side of the leaves and on the young fruits. It develops from the sporidia of the teleutospores by which infection is brought about. On the upper side of the leaves are small sunk patches of reddened tissue (**spermogonia**), and on the under side **cluster cups**, consisting of groups of rust-red **æcidia** on swollen patches of yellowish tissue (p. 39). Since it has been known that the æcidiospores are transferred to cereals, barberry bushes have been removed from the neighbourhood of arable land as a precautionary measure against Black Rust of corn.

The æcidia of **Crown Rust** are found both on seedlings and adult plants of buckthorn. They occur in thick yellow-red cushions on twigs, flowers, flower stalks, leaves, and leaf stalks.

Rusts appear on the tips of the shoots of aspen and willow in the form already described for related pests. In the former it is caused by **Willow Rust** (*Melampsora Hartigii*, Thüm.), of which the Cæoma form appears on gooseberries and currants as *Cæoma ribesii*, Lk. In aspen it is due to **Poplar Rust** (*Melampsora tremulæ*, Tul.), a stage of **Pine Branch Twist** (*Cæoma pinitorquum*, A. Br., p. 124).

One of the higher plants, **Common Dodder** (*Cuscuta europæa*, L.) may here be mentioned as a destructive pest to willows. The leaves and chlorophyll-containing tissue are greatly reduced, so that the nourishment of the parasite is almost entirely derived from its host, round which its stem twines closely (fig. 21, 1). Characteristic suctorial organs or **haustoria** (fig. 21, 2) penetrate into the willow twigs. (Related species attack flax, hemp, hops, and stinging nettles.)

Coral Spot (*Nectria cinnabarina*, Tode) is a fungoid disease to be found on most hardwoods. It settles on woody parts that have been killed by frost (p. 86), and also penetrates into wounds of living trees. The cinnabar-red conidial swellings of the fungus project like red pustules from the bark in large numbers (Frontispiece, 4). The dark-red and much larger perithecia develop much later. The mycelium grows into the wood vessels and colours these black. In consequence of the stoppage of the flow of sap the leaves usually die early, as do the infested branches or even the whole tree. It is a remarkable fact that Nectria does not attack the living cortical tissue and the cambium until the action of frost or desiccation reduces these to a dying condition.

Sycamore Leaf Blotch, found also on maple, is the sclerotium stage of a Discomycete fungus (*Rhytisma acerinum*, Pers.). It appears in the form of large black patches, frequently over 2½ cm. in diameter, on the healthy green leaves of various species of maple and sycamore. They are irregularly distributed on the leaf blade (fig. 35). The asci of the fungus develop on the fallen leaves in spring, and the escaped ascospores are distributed by the wind, and spread the disease. At first yellowish blotches are seen on the green leaves, which assume a blackish colour by midsummer. Sometimes entire avenues and parks are disfigured by this disease. It is a good thing to collect and remove the fallen leaves in autumn.

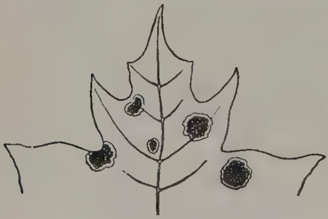

Fig. 35.—Sycamore Leaf Blotch (*Rhytisma acerinum*, Pers.)

Red "Spider" is the name given by gardeners to a small, reddish, eight-legged spinning mite (*Tetranychus telarius*, L.), which sucks the sap of all sorts of trees and shrubs, giving rise to a characteristic dryness of the leaves. The pest is particularly common during the hottest part of the summer, and is able in a short time to do much damage over considerable areas. The shoots attacked usually remain stunted. The chief trees attacked are lime, willows, and horse-chestnut, and the mites are visible as small, reddish spots on the under sides of the leaves. Greenhouse plants, such as *Musa*, and many kinds of ornamental flowering plants are also liable to infestation. It is recognized by remarkable discoloration of the leaves. The green colour is everywhere marked with pale-yellow dots, which later on become yellow or yellowish brown, while sometimes reddish patches may be seen. Every dot corresponds to a place where a mite has pierced the leaf and begun to suck the sap. Owing to this variously coloured punctation the surface of the leaf assumes a mottled appearance.

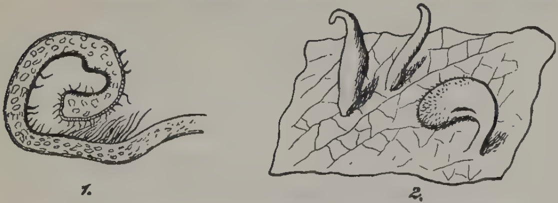

Fig. 36.—Infestation of Lime Leaves by Gall Mites (*Eriophyes*)
1, A rolled leaf. 2, Bottle Galls

The characteristic deformations and injuries produced by **Gall Mites** (*Eriophyes* [*Phytoptus*] spp.) in fruit trees and vines have been described in preceding sections. They find nourishment and reproduce in the galls (fig. 36, 2) resulting from their presence. The larvæ hatch out very quickly from the eggs, and after shedding their skins several times become sexually mature. These mites are parasitic on perennial herbs and woody plants, usually hibernating in the buds, to which they migrate from the galls. They and their eggs are found in the diseased buds in spring. At the end of May and the beginning of June they leave these buds, which in the meanwhile have become brown and more or less dried up, and migrate in large numbers to the young shoots, taking up their quarters in the buds. The irritation set up by the parasites stimulates these to grow to an abnormal size ("big bud"). Galls are for the most part produced only on fairly young tissue, and they begin to appear on the leaves when these unfold. Their development is due to the adult mites, and they serve as receptacles in which the eggs are laid.

The alterations of tissue brought about by *Eriophyes* are of extremely various kind. Sometimes we find on leaves merely a specially abundant production of hairs, different in character according to the particular host (fig. 36, 1). Dense felted patches of striking colour are visible on the green surface of the leaf, and show where the mites and their eggs are harboured. A case has already been described for the vine (p. 108), and similar infestations can be seen in most parts.

Sometimes the presence of mites causes leaves to be folded or rolled, without undergoing any alteration in their general shape (fig. 36, 1), though the infested spots may be thickened, and their edges may be swollen.

Gall Mites may, however, cause all sorts of deformations. In leaves, for example, we find contraction and splitting of the leaf tissue, often associated with the production of hairs and rolling. At the tips of young shoots, and in buds, the deformation usually takes the form of a shortening of the axis and an increase in volume, causing the individual buds to assume a rounded form. This is brought about by thickening of the leaves and scales of the bud, once more associated with the abundant production of hairs. There may also be swelling of the mesophyll, marked externally by the presence of dark blisters (as in the pear, p. 96). Hollow outgrowths known as **Bottle Galls** may also project from the external surface of the leaf (fig. 36, 2), and these may be more than 1 cm. in length. The entrance to such a gall is always on the under side of the leaf, at the place where the infection started. The lining of these galls is richly clothed with abnormally produced hairs.

All the pathological appearances just described may be seen in most of the woody plants of our gardens and parks.

Owing to the numerous researches of Küster (cf. p. 17) great advances have been made of late years in our knowledge of Galls. He and others have been able to produce gall-like outgrowths on leaves by the action of external agents (e.g. by sprinkling with water).

Among phanerogamous parasites occurring in parks two members of the family Loranthaceæ deserve notice. One of these, the **Mistletoe** (*Viscum album*, L., fig. 37), is known to most readers from legends and ancient popular customs. It is an evergreen found on most of our native hardwoods, including fruit trees, and also on the silver fir and Scots pine. Its globular masses with their leathery dark-green leaves are attached by short stems to the branches of the host, and are most conspicuous when all the leaves of this have fallen. As shown in fig. 38, the Mistletoe possesses suctorial roots, by which mineral salts and possibly albuminous matters are absorbed from the host. The value of woods used for economic purposes is diminished by the attacks of the parasite, as holes are formed where the suctorial

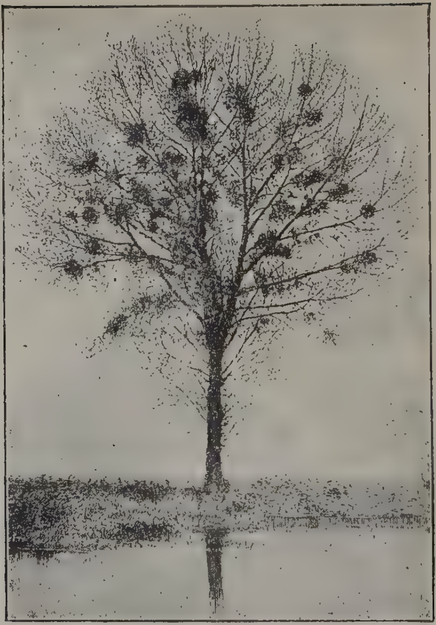

Fig. 37.—Mistletoe (*Viscum album*, L.) on Black Poplar (after F. Cohn)

roots have penetrated. The Mistletoe has only been observed on oaks in Germany in quite recent years (von Tubeuf), but these trees are attacked by another species, the **Oak Mistletoe** (*Loranthus europæus*, R. Htg.), which is unknown in Britain. The damage it effects is of similar nature.

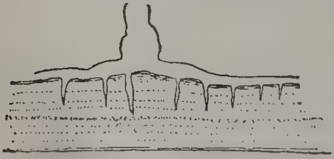

Fig. 38.—Suctorial Roots of Mistletoe (*Viscum album*, L.) penetrating a Twig

In both cases dispersal is brought about by birds, particularly thrushes, the sticky seeds of the parasite adhering to branches.

Still other oak pests may here be mentioned. One is a fungus (*Rosellinia quercinia*, R. Htg.) which produces **Oak Seedling Disease**, very destructive in North Germany. It destroys the roots, causing the host to gradually dry up. There is a hibernating sclerotial stage, giving rise to a number of mycelial strands, which twine round the roots of adjacent plants and rapidly spread the disease. **Oak Canker**, a bark disease, is caused by a closely related fungus (*Aglaospora taleola*, Tul.).

Among the large number of insects which attack the oak, something like 100 in number, the **Processionary Moth** (*Cnethocampa processionea*, L.) is especially worth notice. The caterpillars of this moth completely devour the young leaves and only reject the veins of the old ones. In extreme cases a tree may be completely stripped of foliage. When the infestation appears for several years in succession, older oaks become "stag-headed", i.e. their crowns decay, while younger ones may perish altogether.

Large numbers of caterpillars are associated together, for they live in companies from the time they hatch out of the groups of hibernated eggs, feeding, casting their skins, and pupating at the same time. They rest in sheltered spots, especially at the forks of branches, where they construct large conspicuous nests from excrement and cast skins fastened together by threads of silk. After sunset they come out to feed, crawling in procession one after the other to the leafy crown of the tree. After having done a great deal of damage, they go back to their resting places in the morning in similar fashion.

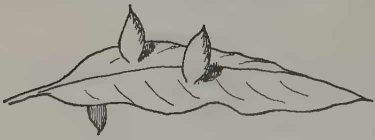

Fig. 39.—Beech Leaf Galls, caused by *Hormomyia fagi*, R. Htg.

Beeches have their special pests among microscopic organisms. A fungus, *Nectria ditissima*, Tul. (apple canker), closely related to the one producing Coral Spot (p. 111), settles on wounds due to external agents (frost, hail, &c.), especially in copper beech. Its mycelium penetrates into the wood. The disease can be recognized externally by the presence of cankerous swellings where the bark is ruptured.

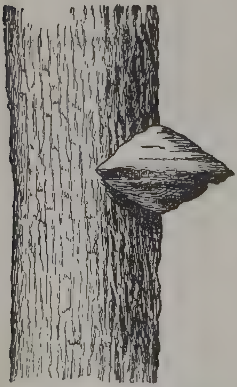

Fig. 40.—Tree Fungus (*Polyporus fomentarius*, L.)

Phytophthora omnivora, de By. [=*P. fagi*, R. Htg.] closely related to the fungus causing Potato Disease, is very harmful to beech seedlings, which quickly blacken and perish, the hypocotyl shrivelling (**Beech Seedling Disease**).

The leaves of copper beeches are often studded by galls, produced by perforations of the ovipositor of the Beech Gall Midge (*Cecidomyia* [*Hormomyia*] *fagi*, R. Htg.). As shown in fig. 39 we have here, as in galls produced by mites, swellings of the leaf tissue, containing hollows inhabited by the larvæ.

Most of our native hardwoods are seriously injured, like fruit trees, by **Tree Fungi** (*Polyporeæ*). The bracket-like spore-producing fruit body of one of these is represented in Fig. 40. **Dry Rot** (*Merulius lacrymans*, Jacq.), which destroys timber, is caused by a closely related form.

CHAPTER VIII

PLANT DISEASES—CONIFEROUS WOODS

The fungoid pests of conifers attack various parts—roots, wood and bark, and cones.

The **Honey Fungus** (*Agaricus melleus*, L., fig. 41), a Basidiomycete species, is one of the commonest root parasites. It is found as a saprophyte upon a great many hardwoods—beech, birch, species of Prunus, mountain ash—and as a wound parasite on oak. Stumps of such trees infested by this species if allowed to remain in coniferous woods are able to cause much destruction, for it is a true parasite of conifers. It mostly attacks pines, Weymouth pines, and spruces, which gradually die as the result. It is particularly harmful to young trees three to fifteen years of age, but it is also able to destroy those ranging up to 100 years old. The pathological changes to be seen are somewhat as follows.

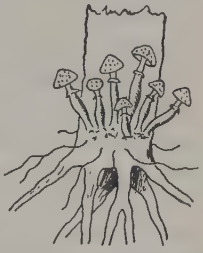

Fig. 41.—Honey Fungus (*Agaricus melleus*, L.) with Mycelial Strands

Where the bark has been removed from the roots and base of the trunk, the mycelium appears as a dense snow-white covering. Connected with it are long copiously branched blackish-brown strands, some of which break through the bark of the roots, while others grow outside it. These *rhizomorphous* or root-like strands are the chief source of infection, for they grow underground from one tree to another. They perforate the cortex of healthy coniferous roots, which they traverse in the form of snow-white bands—often spreading fan-wise—reaching and destroying the bast and cambium. They also cause extensive damage to the sap-wood, destroying the resin-passages and disintegrating the adjacent tissues so as to make large cavities. The destructive work is chiefly effected by a fine feltwork of hyphæ developed externally at the tip of each strand, while other fibres penetrate far into the wood, chiefly along the medullary rays. The cell-contents and cell-walls break down into resin, which, owing to its weight, either runs down between the wood and cortex, or flows out into the ground through ruptured places. Hence the idea that it was a kind of canker of the soil. The spore-producing fruits or **toadstools** are usually developed in damp autumn weather on the bark of dead stumps or on the strands growing freely through the ground. We then everywhere see the honey-brown caps with their reddish-brown stalks crowded together on or near the host plants they have killed.

An interesting peculiarity of wood exhibiting "white rot" as the result of the attacks of this fungus is its luminous appearance in the dark. This phosphorescence is a result of the vital activity of the white mycelium, and soon ceases when it dies.

Unfortunately the disease is externally recognizable hardly a year before the death of the tree. Besides the symptoms described—thickening of the roots and base of the trunk and flow of resin—may be further mentioned yellowing and shedding of the needles, and death of the shoots.

Robert Hartig describes the **Root Fungus** (*Trametes radiciperda*, R. Htg.) as the most serious parasite of conifers. It causes **Root Rot** of the most various species, and **Red Rot** of the wood. As in the Honey Fungus, infection goes on underground from one tree to another, and under some conditions it may be disseminated by spores.

The destruction of the host plant spreads from the root, but the course of the disease varies in different species. In most cases the mycelium grows up the stem to a considerable height, but in Scots pine this is prevented by the excessive production of resin at the base.

As soon as the mycelium has penetrated the living cortex there are several possible directions along which the wood may be completely destroyed. The hyphæ can grow rapidly in a vertical direction, their course being indicated by a violet discoloration, due to ferment action, which usually causes the cell contents to become dark. As these disappear, the colour also goes, dark spots here and there remaining. The wood becomes more and more porous, ultimately breaking up into fibres. The hyphæ can also make their way into the constituents of the wood, piercing their walls and ultimately reaching the pith. The decomposition of the wood begins by a conversion into cellulose, which rapidly becomes dissolved. The very pernicious nature of Red Rot is due to the rapidity with which it permeates the trunk.

Besides the changes in the wood, attention must be given to what goes on in the cortex. From the place where the hyphæ penetrate, the mycelium gradually grows to the ends of the roots and into the stem, which takes a comparatively long time. The cortex and roots are thus killed, and the tree gradually dies in consequence. The spore-producing bodies, which project externally, are developed from the hyphal network present in the cortex. In spruce they are present only on the roots, but in Scots pine they are mostly to be seen near the ground at the base of the trunk. They are yellowish-white swellings which fuse together into a wavy crust from $\frac{1}{4}$ to $\frac{1}{2}$ m. broad, looking like lobed cakes, and porous in places.

The **Pine Fungus** (*Trametes pini*, Frk.) is closely related to the species just described. It is essentially a destroyer of the wood, causing the trees attacked to become hollow, and producing what are known as **Ring Shakes** and **Heart Shakes**.

The germinal hyphæ penetrate to the wood through wounded spots, dissolve the cell walls, and quickly reach the heartwood without injuring the sapwood. The internal rings of the wood become red brown in colour, and, owing to the dissolving of the cell walls, holes everywhere make their appearance, lined by white tinder-like mycelium. The elements of the wood may perish completely in course of time. Bracket-like spore-producing bodies, resembling those of the Tree Fungus, and brown in colour (fig. 40), are developed on the bark from the external mycelium. Dispersal takes place very rapidly, the spores being carried by the wind to freshly wounded spots, where they quickly germinate.

Some of the diseases of conifers caused by Rusts require mention, one being **Pine Cluster Cups** or **Pine Canker.** It is due to the fungus *Peridermium pini*, Willd., which gives rise to blister-like projections on the stems and branches of pines. These are orange yellow in colour and developed from the mycelium in the bark. After a time they burst, and the spores within are blown away by the wind, leaving only the colourless investment behind. The spores penetrate wounds in the bark, where the mycelium spreads very rapidly and vigorously. The hyphæ grow between the medullary rays and the cells of the cortex and bast, They can also penetrate into the wood, converting the cell contents into resin, much as in the case of the Honey Fungus. Parts thus attacked become blocked up with resin, so that the ascent of water from the soil is checked. It is in this that the great harmfulness of the Rust consists, for by the spread of the mycelium more and more resin is formed. Canker-like outgrowths appear in increasing numbers on the infected branches, which gradually become surrounded by them. They are not arranged regularly. The branches so affected die, and terminal ones are particularly liable to attack. It may be added that *Peridermium pini* also attacks the needles of young pines, causing Rust. Orange-yellow outgrowths appear on the needles, and when they burst, the spores developed within them are set free. The fungus is able to hibernate in the needles, causing a fresh outbreak of the æcidial stage next spring. The **æcidiospores** do not as a rule germinate on pines, but require other hosts (*Vincetoxicum officinale*, *Senecio* spp.) for their further development. Upon these they ultimately give rise to the **teleutospore stage** (*Cronartium asclepiadeum*, Willd.).

Another heterœcious form is **Weymouth Pine Rust** (*Peridermium strobi*, Kleb.). Its mycelium causes elongated outgrowths on the branches of Weymouth pine, and on these again red-yellow blisters make their appearance. The **æcidiospores** germinate on the leaves of gooseberry and currant to produce the **uredospore** and **teleutospore stages** (*Cronartium ribicolum*, Deitr.). The mycelium may become perennial in Weymouth pine, developing æcidia every spring (p. 89).

Pine Branch Twist is also due to a Rust (*Cæoma pinitorquum*, A. Br.). It appeared in Germany during the seventies of last century and worked havoc in pine nurseries. The attacks of the fungus are particularly favoured by the aspens which are so frequently planted, for the golden-yellow **uredo** spots and the dark **teleutospore** patches which develop on the epidermis of their leaves (*Melampsora pinitorqua*, Rostr.) are stages in the life-history of the fungus which in its cæoma form brings about characteristic twistings of pine shoots in May. Before the young shoots have fully developed, elongated swellings appear at their tips, at first yellow and then reddish yellow in colour. The spores escape from them by rupture of the cortex, and the formation of cracks is associated with the growth of abnormal swellings and the excessive formation of resin. The cracks and deformations on a shoot are distributed in such a way as to give a twisted appearance; hence the name of the disease. Here again the mycelium is able to hibernate in the host, producing fresh æcidia every year.

Silver Fir Canker is produced by another Rust (*Æcidium elatinum*, Alb. et Schw.) which also causes Witches' Brooms. The teleutospore stage is found on species of *Stellaria* and *Cerastium* (*Melampsorella cerastii*, Pers.).

Infection usually takes place at wounded places. The mycelium may become perennial, as in Rusts already described, and it penetrates to the cambium, setting up unusually quick and vigorous growth. Owing to the abnormal development of the cortex and wood, blister-like swellings and cankered spots are produced, and may assume a very large size. These deformations are almost always associated with cracks, which favour the entrance of other parasites of the wood. Witches' Brooms are usually formed when the infection is in the neighbourhood of the buds. The modified branch is usually recognizable by its growth in the direction of the main shoot. The mycelium grows in its cortex and also deforms the needles. These are relatively small and contain but little chlorophyll, being consequently of a yellowish colour. During late summer a double series of rusty-red **æcidia** develops on their under sides, and the spores are dispersed soon afterwards. The needles are quickly shed as a result. Since the hibernated mycelium penetrates the young shoots of the next year, the deformations described once more make their appearance.

The damage done to silver fir is increased by injuries from frost, which render the diseased parts more accessible to the attacks of fungi and insects.

One of the most harmful diseases of larch plantations is **Larch Canker** (*Peziza Willkommi*, R. Htg.), of which the apothecia are sometimes to be found in large numbers on fissured parts of the bark. In this disease, again, spores can only enter by wounds on the host, and when there is sufficient dampness to enable germination. The very luxuriant mycelium grows actively in the cortical tissue and sometimes penetrates the wood, even getting as far as the pith. The resulting interference with the passage of sap in the tree naturally has a very deleterious effect. The tree endeavours to protect itself from the parasite during the vegetative period by forming an extremely thick layer of cork between the healthy and diseased tissue. The cortex of the cankered place external to this defensive boundary consequently becomes disintegrated and a flow of resin from the interior is rendered possible. The cankers enlarge again in autumn, as the mycelium grows out afresh from the cambium into the cortex. Sometimes larches have to fight with the parasite for years, gradually becoming stunted and crippled as a result.

For the distribution of the pest damp weather is essential, for it is only then that the apothecia are able to mature. Failing such weather, the ripe spores quickly perish within the fruits.

There is another kind of fungoid disease which assumes an epidemic character under unusual meteorological conditions. Prior to 1892 the fungus *Cenangium abietis*, Duby, was only known as an occasional harmless parasite, but in that year it caused wholesale disease of young pine plantations in about 200 of the chief forestry districts of Prussia. Frank-Schwartz has given a detailed account of the various symptoms associated with the course of the disease and described the stages of the epidemic. The parts especially liable to attack are the shoots of young Scots pines, which die back from their tips. The infection spreads continuously downwards from the buds, attacking the needles from their bases and causing them to perish. The cortical tissue is gradually destroyed and a brownish colour is assumed by the adjacent parts of the cambium, as also by the medullary rays and pith. The fruits of the fungus project from injured spots on the needles and cortex as blackish-brown knobs and cushions. The spores generally first mature in, and are dispersed from, diseased parts which have fallen on the ground, for there the necessary moisture is most abundant.

Peridermium pini, Willd. (p. 123) is not the only Rust attacking the needles of conifers. A number of such pests are of considerable importance, but, as they are very similar to the Peridermium, a brief account must suffice. **Spruce Blister Rust** (*Æcidium abietinum*, Alb. et Schw.) is harboured in the æcidial stage by the needles of spruce, while its teleutospore generation develops on rhododendron. **Spruce Rust** or **Blight** (*Chrysomyxa abietis*, Wallr.) infests the needles of young spruce shoots in the form of yellowish patches, on which in late summer the orange-yellow Rust thickenings may be observed as longitudiual streaks.

Silver Fir Rust (*Æcidium columnare*, Alb. et Schw.) has a preference for attacking and destroying the needles of silver fir. Its teleutospore stage (*Calyptospora Goep-*

pertiana, Kühn) is found on the cowberry (*Vaccinium Vitis-Idæa*).

Among other fungi attacking the needles of conifers are members of the *Hysteriaceæ*, which give rise to **Pine Scab** or **Scurf**. Among these may first be mentioned *Hysterium* [*Lophodermium*] *pinastri*, Schrad., undoubtedly the most harmful pest of young Scots pines (fig. 42). The disease at first makes its appearance in August in the form of reddish-brown patches on the needles, where the early stages in the life-history are passed. By means of the microscope the mycelium of the Lophodermium can be made out. During the same autumn the blackish spermogonia develop on the diseased needles, which quickly turn red during the following spring, are cut off by a cork layer from the stem, and fall to the ground; hence the term "leaf cast".

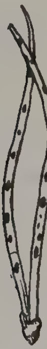

Fig. 42.—Needles of Scots Pine attacked by *Hysterium pinastri*, Schrad.

Spruce Scab or **Scurf** is caused by *Hysterium* [*Lophodermium*] *macrosporum*, R. Htg. The infestation is very similar to that last described, and the leaves are cast in the same way, but here older plantations (fifteen to thirty years) are more particularly attacked. Another very similar disease is **Silver Fir Scab** or **Scurf** (*Hysterium* [*Lophodermium*] *nervisequium*, D. C.), which affects needles of two years old and upwards. In spite of the wide distribution of the parasite but little damage is effected.

We have also **Larch Scab** or **Scurf** (*Sphærella laricina*, Hess), which may be harmful to plantations of various age, particularly in damp years.

Among the fungoid pests of conifers may be noticed a Rust (*Æcidium strobilinum*, Alb. et Schw.), which is to be found on the inner surfaces of the scales of spruce cones. These, while still green, are attacked and killed by the mycelium of the fungus. The teleutospore stage (*Pucciniastrum padi*) is harboured by the bird cherry (*Prunus Padus*, L.).

Insects are among the most dangerous enemies of coniferous trees. The interest attaching to them is primarily of an economic nature, for some of those now to be considered may appear as an epidemic and destroy entire woods in a short time.

The damage effected is of a direct kind, such as devouring or boring of various parts, or it may be stripping of the bark, while pathological changes in the growth or development of tissue are not particularly obvious. A brief enumeration of the more important kinds will therefore suffice.

Moths and **Beetles** here require special notice. Various **Bombycids** among the former are particularly harmful to coniferous woods. The caterpillars of the **Pine Processionary Moth** (*Cnethocampa pinivora*, Tr.), closely allied to a pest of the oak (p. 117), are extremely harmful to pines. The **Pine Moth** (*Bombyx pini*, L.), however, does far more damage. This pest may completely strip the leaves, and is well known in plantations. The caterpillars of the **Black Arches**, **Nun**, or **Spruce Moth** (*Liparis monacha*, L.) infest in great numbers very many hardwoods and conifers, especially the spruce. As other extremely destructive pests of conifers may be mentioned

Noctua griseovariegata, Goetze, and the **Pine Loopers** (*Geometra piniaria*, L., and *G. liturata*, Cl.), representing respectively the **Owlet Moths** and **Geometers**, and of which the caterpillars may entirely destroy the foliage.

Among **Tortricid Moths** some of the species of *Grapholitha* are notorious pests. One of them, for example, attacks the foliar spurs of Scots pine, causing the needles to grow in rounded bundles. Others again lead to the development of **resin galls**, which may be more than 3 cm. in diameter on the twigs of the same species.

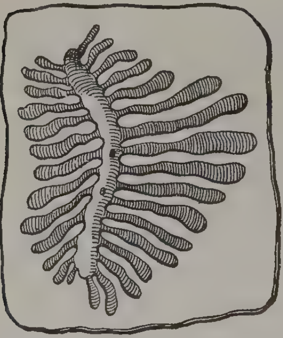

Fig. 43.—Diagram of Mother and Larval Tunnels of a Bark Beetle

Galls may also be produced on conifers by **Plant Lice** belonging to the genus *Chermes* (bud galls and other deformations of the shoots). **Gall Midges** (*Cecidomyia*) are responsible for similar pathological appearances.

Bark Beetles (*Scolytidæ*) are among the most harmful tree pests belonging to the Coleoptera. The fertilized female excavates a broad passage (mother tunnel) under the bark, and gnaws out pits on either side of this, an egg being deposited in each. When the larvæ are hatched out, each of them makes a lateral passage (larval tunnel) in the same plane as the mother tunnel, so that a system resembling that depicted in fig. 43 is formed, the pattern varying with the species.

Diseases due to **inorganic influences** are much the same as those described in earlier chapters for garden and fruit trees. One case, however, may be specially mentioned.

Besides the leaf cast mentioned on p. 128 as the result of fungoid attack, R. Hess also distinguishes **shedding of the leaves** brought about by **frost** and **drought**. Under the former he includes cases which "can be referred to repeated chilling caused by radiation from ground open to the sky and not covered by snow". Spring or autumn frosts thus bring about a shedding of the needles. It may here be noticed that a marked difference in temperature between cold at night and heat during the day has particularly deleterious influence on plants. Shedding of leaves as the result of frost is especially marked, as a rule, in cold damp summers when a normal formation of wood in the shoots does not take place. As in leaf-cast due to fungoid disease the needles assume a red colour before they fall off.

Shedding of leaves as a result of dry conditions is related to summer drought. The needles dry up because the increased transpiration resulting from great heat is not compensated for by absorption from the soil. But the leaves may die and fall off when the temperature is high even when there is sufficient moisture in the soil. This is not so much due to insufficient absorptive capacity on the part of the roots as to too great coldness of the soil.

The economic importance of protection of woods and forests against various harmful factors, some of which are universal in their action, is sufficiently obvious when we remember that over 740 million ac. are occupied by woods and forests in Europe, those of Germany amounting to 34,580,000 ac. Scots pine alone, furnishing the most useful timber, and of which the diseases have here been treated most fully, makes up 44 per cent of the German forest area. In the province of Brandenburg alone there are 3,290,000 ac. of Scots pine.

CHAPTER IX

TREATMENT OF PLANT DISEASES

Even in ancient times attempts were made to deal with plant diseases, as is sufficiently attested by the writings of those classic writers who deal with agriculture. The old culture nations not only endeavoured to treat cases of acute disease, but also attempted to devise preventive measures. It may be mentioned as an example that the ploughing in of certain leguminous crops was a widely distributed practice in early times.

Since, however, the most important causes of pathological appearances were mostly but imperfectly known prior to the middle of the nineteenth century, the methods of treatment adopted were purely empirical. And as in many cases human medicine proceeds in a similar fashion at the present time, so also with plant protection. Even now our knowledge is not sufficient fully to explain the therapeutic (i.e. fungus-killing) action of the copper-lime solution which is almost universally employed. The methods of dealing with plant diseases, which have resulted from experience, have nevertheless been productive of great results.

The knowledge of individual diseases has taught us that many acute cases can be treated either surgically or by the employment of chemical measures, and the foundations of **Plant Hygiene** have thus been laid. In the development of this branch of knowledge Sorauer has been particularly prominent, and some of his axioms may here be mentioned.

The plant breeder has long been aware that any particular species requires a special habitat and favourable vegetative conditions, and that in a particular soil and climate he must only cultivate species able to offer the maximum resistance to unfavourable organic and inorganic influences. He must also use only **healthy clean seed**, as otherwise fungoid pests and weeds of the previous year may easily be introduced into his fields.

A suitable **rotation of crops** is of equal importance for preventing all kinds of infectious diseases and other influences that weaken seedlings. These preventive measures also include the destruction of wild plants which harbour parasites that may be transferred to crops. In this connection the heteræcious Rusts, which have been frequently mentioned in earlier chapters, deserve special notice.

For details regarding other similar measures employed by the cultivator reference must be made to other works. It may here be mentioned that material to be used for sowing should be kept in suitable places, affording protection against pests, which easily develop in warm damp air. Besides the cellars which have been employed for storing produce, special **clamps** have been used with very good results in more recent times. They are constructed on levelled parts of the field and covered by layers of straw and earth. A few examples will now be given of the very numerous preventive measures against atmospheric influences.

In dealing with fruit culture and viticulture a detailed account was given of the deleterious action of **frost.** The means of combating this are of very varied nature. At one time such plants growing in the open air as were most exposed to frost were covered with all sorts of material. Leaves, brushwood, moss, straw, and mats were all used for this purpose, as being bad conductors of heat.

In many cases, as in young plantations, the construction of a **shelter belt** (of spruce or Scots pine) is recommended on the north-east, east, and south-east sides, especially in places adjoining cold meadows (Richard Hess, *Forest Protection*, &c.).

Smudge fires are particularly valuable as a protection against frost. They are especially employed in the culture of vines and fruit. Should a night frost be anticipated, heaps of inflammable material or flat receptacles of galvanized iron filled with gas tar and sawdust (or straw and brushwood) are placed at moderate distances apart (about 15 m.) on the windward side of the land to be protected. After these have been lighted a thick black smoke is spread over the planted area, over which it may hang for hours. Such a covering of smoke acts like a cloud by reducing radiation. More recently "frost faggots", invented by Lemström, have been used for generating smoke. These consist of conical masses of compressed peat impregnated with smoke-producing substances, and traversed by a longitudinal perforation.

Preventive measures are also employed against other atmospheric agents besides frost. As an example may be mentioned the hedges serving as **wind screens**, which have been employed in coastal lands from very early times to the present day as a means of sheltering cultivated areas from wind and storm.

When dealing with plant and animal pests the cultivator is concerned with **direct means of extermination**—especially of the reproductive stages—as well as with preventive measures. Some animals are destroyed by **mechanical means**, associated with ingenious arrangements for attracting such pests.

Chemical means of destruction are also used, and these are distinguished as fungicides or insecticides when used for the destruction of fungi and insects respectively. They are designed to kill pests without injuring the host plants.

1. MECHANICAL MEANS OF DESTRUCTION

Special **lamps** have been constructed for attracting nocturnal insects such as moths, e.g. **Owlet Moths** (**Dart Moth**—*Agrotis segetum*). Brightly burning lamps giving a bright light, and capable of burning the whole night, are placed in fields or vineyards on wooden frameworks at a height of 1½ m. above the ground. Boxes, usually filled with dilute molasses, are placed beneath the lanterns, the walls of which are somewhat slanting. Moths are attracted by the light, and as soon as they strike against the glass slide down into the boxes of molasses, where they are drowned.

Obstacles and **traps** are placed in the way of other insects as they move from place to place. **Beetles** and

caterpillars, for example, are caught in trenches, and **Mole-crickets** in pits.

Sticky substances are used in combating the harmful **caterpillars** of the Pine Moth, Nun Moth, and Loopers, as also various **wingless beetles**. The object is to prevent such pests from creeping up to the leafy branches from the ground. Such substances as tar, which dry very slowly, are mostly used, and these are smeared directly on the bark of older trees, or on paper bands surrounding the trunks of younger ones. A similar purpose is served by walls of brushwood smeared with sticky substances, which entangle wandering caterpillars.

Lure plants are used in dealing with **Nematodes,** which damage large areas of arable land, and also in the case of injurious **Flies**. These plants must be sown so as to be well developed at the time when the pest normally reaches its reproductive stage on the host plant. When the parasite has collected in large numbers on the lures, these are collected and destroyed, and sowing of the crop can then commence.

Grease-banding, flea-beetle machines, and similar contrivances can only be mentioned. They are all designed for catching pests by means of sticky or adhesive substances.

One useful measure is **jarring** insects from trees and shrubs. They can be caught in large tin funnels or in umbrellas.

2. Chemical Means of Destruction.

Various spraying machines and bellows have been devised for distributing the various mixtures, solutions, and powders described under this heading. Some are carried in the hand, others on the back, and others again are taken over the land on carts.

(*a*) **Insecticides**

Among these, various **fatty substances** of animal or vegetable nature, in the form of emulsions or soaps, play an important part. **Turpentine** or **petroleum** are used in a similar way. The most important insecticides prepared from vegetable substances are **insect powder, tobacco** infusion and powder, and infusion of **quassia.** Details are given below.

Spraying with **water** only has a fatal effect on Aphides. **Hot air** is employed for killing beetles infesting leguminous seeds, also Corn Weevils and the Corn Moth. It is obvious that seeds and fruits are the chief things treated in this way, and the temperature must not exceed 60° C., for otherwise most seeds will lose their power of germination.

The use of **carbon bisulphide** in combating *Phylloxera* has already been mentioned (p. 106). The value of the remedy is sufficiently attested by the fact that 222,225 sq. m. of ground in Prussia alone were saturated with carbon bisulphide for this purpose in the year 1902.

In dealing with mites, spinning mites, and scale insects, a mixture of **liver of sulphur** with **quicklime** or **soft soap** is applied by means of a special spraying apparatus.

Paris-green mixture is another very potent kind of liquid dressing. It is composed of Paris green and water, with the addition of milk of lime prepared from quicklime.

Antinonin, a compound of potassium-orthodinitro-cresol, has been recommended for combating the Nun Moth, but its efficacy has been much disputed. Infusions of various bitter substances have also been used for the destruction of insect pests, especially Aphides and naked caterpillars. Among those which are particularly active may be mentioned **quassia, aloes, elder-flowers, wormwood,** and **tobacco.** The quassia infusion is prepared from quassia chips, with an addition of soft soap, and employed as a spray.

Tobacco in the powdered form can also be used, being dusted on by the same kind of bellows as used for distributing flowers of sulphur (p. 141). An infusion of tobacco may be employed as a spray, either alone or mixed with petroleum emulsion.

Petroleum is a well-known insecticide, but in its pure form can only be applied to stems and branches with a strong bark, as it kills the more delicate parts of plants. For such parts a mixture of petroleum with water or emulsion of soft soap is used in specially constructed syringes. **Insect powders** are also a good remedy for pests, especially the Vine Cross Moth. In the case of the smaller insects they are used as powders, but mixed with soft-soap emulsions for dealing with larger ones.

Various mixtures are recommended for coping with

Aphides, and they can be applied with a brush to the colonies of these insects. Among them are **Fuhrmann's Fluid** (horse fat, train oil, spirit, and cooking salt), **Nessler's Fluids** (soft soap emulsion and fusel oil, with either spirit or carbolic acid), and **Göld's Tincture** (resin dissolved in turpentine, carbon bisulphide, and sweet milk).

(*b*) Fungicides

In order to keep seed corn from being contaminated with the spores of fungi, especially those of **Smut**, treatment with **hot water** gives good results. The grain is shaken up in suitable vessels containing water at a temperature of 52° to 56° C. After from ten to fifteen minutes the grain is taken out and spread in thin layers to dry.

The same result can be obtained by means of **hot air**, the seed corn being exposed preferably for several hours to a temperature of 50° to 60° C. A baker's oven will answer the purpose well.

Copper and **sulphur compounds** are the most important chemical fungicides. Botanists have long known that copper is one of the most harmful poisons for plant life. The small traces of copper which collect in brass taps are sufficient to kill algæ.

An aqueous solution of **copper sulphate** is used for pickling seed corn. The best-known methods of preparation are given by Julius Kühn and Linhart. Either the simple solution may be used or milk of lime added.

The best-known and most widely distributed fungicide is **Bordeaux mixture**, which consists of copper sulphate solution and milk of lime, prepared separately, and mixed together in the same vessel with constant stirring. In composition the mixture is made up of a solution and a precipitate. The latter is insoluble basic copper, the former, sulphate of lime. For preparing 100 litres of 1-per-cent solution, 1 kg. of copper sulphate is dissolved in 50 litres of water, and 1 kg. of quicklime slaked in 50 litres of water. For a 2-per-cent mixture double the quantities, and for a $\frac{1}{2}$-per-cent mixture half the above quantities of copper sulphate and quicklime are taken.

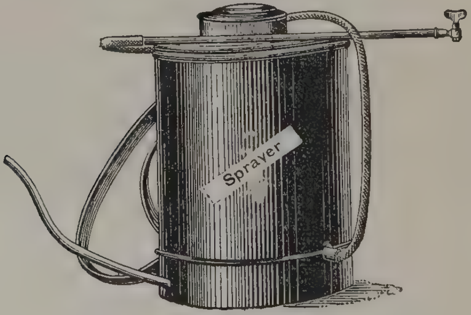

Fig. 44.--Simple Knapsack Sprayer

Many different sorts of apparatus are used for spraying with Bordeaux mixture. A simple knapsack type used in vineyards is represented in fig. 44, which clearly shows the openings for filling and discharge. (It may expressly be stated here that it is not the object of this little book to exhaustively describe the individual remedies and varieties of apparatus employed in combating the various diseases of plants.)

Bordeaux mixture is essentially a preventive, but its mode of action is not yet clearly understood. According to recent researches of Ruhland, fungus spores getting ready to germinate excrete certain substances which are able to dissolve the precipitate of poisonous copper oxyhydrate, and the spores are killed by absorbing this solution.

An **encrustation method** of pickling seed corn, giving good results, has been recommended by von Tubeuf. After thorough cleaning, the corn is put in a willow basket and immersed in a vessel filled with a 2-per-cent Bordeaux mixture. The grains are thus covered with a blue coating and are afterwards dried.

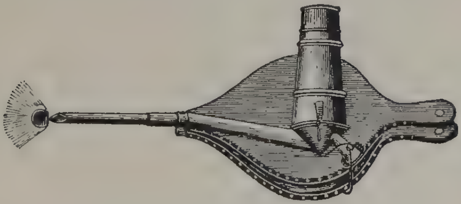

Fig. 45.—Sulphur Bellows

Mixtures of copper sulphate solution with washing soda, or of copper carbonate with ammonia, can be used in the same way as Bordeaux mixture.

Flowers of sulphur is another application that has been widely used. Its power of forming sulphurous acid when exposed to warmth and air makes it an excellent fungicide. It is particularly useful in the case of Mildews which are superficially situated on leaves and other green parts, but it must be applied as an extremely fine powder. For dusting it on, a bellows is used provided with a receptacle for containing a quantity of the powder.

As a preventive against various **vine diseases** (Grape Rot, Chlorosis), aqueous solutions of **green vitriol** (copper sulphite) can also be employed. Dilute solutions of **formic aldehyde** (formalin) may be used for pickling seed corn, especially for the prevention of Smut.

Surgical methods afford the simplest way of dealing with the diseased parts of trees and shrubs. Success will only be attained, however, when the pest to be combated is unable to hibernate unseen in the bark or wood. In such cases the diseased parts are simply cut off and destroyed. In order to prevent parasites from settling on the wounds caused by the operation, these should be thoroughly covered with coal tar or grafting wax.

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